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The role of the scientific society

Progress in all branches of learning is dependent upon the exchange of information between workers pursuing similar lines of study. Such an exchange is of particular importance in science, where the aim is primarily to collect facts and to interpret them in terms of general principles. Science is exceptional in that its interpretation is comparatively little influenced by the opinions of individuals. While theories may need to be revised or even abandoned altogether as new facts are discovered, the facts themselves remain as permanent aids to future workers. The progress of science is therefore essentially a cumulative one, and the modern scientist can normally build his own work on the foundations established by his predecessors. This stability is lacking in branches of learning where interpretation is coloured by personal, national, or political bias. In literature, music, or painting, for example, the accepted standards of one generation may be—and frequently are—scorned by the next.

The progress of science having been so dependent upon the rapid exchange of new knowledge between workers in the same field, scientific societies, of which the main purpose is to facilitate this exchange, have proved of great historical importance. They were formed in some sort almost as soon as experimental science became established. Crafts and guilds for the handing on of technical knowledge from one generation to another are, of course, almost as old as civilization itself, but as their purpose is rather to preserve existing knowledge than to extend it they can scarcely be considered as scientific societies in the accepted sense.

One of the earliest scientific societies of which we have certain knowledge was that of the Ikhwān al-ṣafā', or Brethren of Sincerity, established at Basra about 983, which endeavoured to reconcile Greek science with the Koran. The members discussed scientific, philosophical, and mathematical subjects, and wrote a series of fifty-two treatises which comprised a sort of encyclopaedia. Seventeen of these treatises dealt with natural sciences and fourteen with mathematics and logic. The interests of the Brethren of Sincerity had much in common with those of the philosophers who, centuries later, formed the Royal Society in London. They sought explanations of tides, eclipses, earthquakes, and other natural phenomena, and recognized, for instance, that sound is produced by vibrations of the air, though they could offer no satisfactory explanation of why simultaneous sounds do not mix.

In Europe, the earliest scientific societies were formed in Italy. In 1560 Giambattista della Porta founded the *Academia Secretorum Naturae* at Naples, membership of which was conditional upon making some discovery in natural science. Porta himself made many important physical observations. He recognized the heating effect of light rays and may also have been the first to use a lens in a camera obscura. In 1603 the *Academia dei Lincei* was founded by Federigo Cesi, Marchese di Monticelli. Among its earliest members was Galileo. The *Accademia del Cimento* was founded at Florence by Leopold de' Medici in 1657. It was an institution for experimental research, and though it lasted for only ten years its reports, published in 1667, form a landmark in the history of science. Torricelli and the physiologist Borelli were among the members of the *Cimento*.

In France the *Académie des Sciences* (1666) evolved from the frequent meetings of a group of scientists, including Descartes, Gassendi, and Pascal. This informal club was eventually given official status as a result of the interest taken in it by Colbert, and Louis XIV made grants of money to it and to its members. Later members included Laplace, Buffon, Jussieu, and Lavoisier. The

Russian Academy of Sciences, founded in 1724, was modelled on the French *Académie*.

In Britain the need for a society for the discussion of scientific matters began to be felt early in the seventeenth century, when the meetings at Gresham College of John Wallis, J. Wilkins, J. Goddard, C. Ent, Robert Boyle, W. Petty, and others resulted in the formation of the Philosophical or Invisible College. From these meetings originated the Royal Society (granted its first Royal Charter by Charles II in 1662), which is today by far the most celebrated scientific society in the world. The Manchester Literary and Philosophical Society, which numbered John Dalton among its many distinguished members, was founded in 1781.

These early scientific societies were representative of science as a whole, for though their members might have a particular interest in physics, chemistry, biology, etc., they were in general natural philosophers with catholic interests. The rapidly increasing extent of scientific knowledge, however, compelled scientists to devote their attention chiefly to one only of the main branches of science. By the end of the eighteenth and the beginning of the nineteenth century, scientific societies appropriate to these specialized interests were being formed. Typical of them were the Geological Society (1807) and the Astronomical Society (1820). In this issue we publish an article on the Chemical Society (1841), which is celebrating its centenary this year after a delay occasioned by the late war. Similar societies were formed on the Continent. The French Chemical Society was founded in 1857 and the German Chemical Society in 1866–7.

The value of scientific societies, as remarked above, lies chiefly in their facilitation of the speedy exchange of new information. Almost from the first they have done this by the publication of scientific papers in their own journals, as well as by arranging lectures and meetings. Today, when scientific work may be pursued along similar lines in many different parts of the world, opportunities for personal contact at lectures and meetings are necessarily insufficient, and the journals published by the scientific societies are correspondingly important. Increasing specialization has brought into existence scores of new scientific societies, studying such specialized branches of science as microbiology, biochemistry, geophysics, and so on. Many of these societies have members in all parts of the world, and though their occasional meetings and lectures are very valuable their main value lies in their journals and other publications, through which all the members can be kept informed of the work being done by their colleagues.

Those scientific societies which have been able to acquire permanent premises have also served a most useful purpose by building up libraries. In them they have gathered together not only complete sets of their own publications but also of those contemporary journals and books which are of value to their members. The libraries of the scientific societies, particularly of those which have been long established, are therefore invaluable to the student. Several of the older societies are also custodians of many articles of historic interest. Besides contemporary portraits of their more distinguished members they often possess manuscripts, apparatus, and personal belongings of the great scientists of the past. Such heirlooms have more than a merely antiquarian interest, for they serve to arouse and nourish the sense of dignity and continuity so essential to the maintenance of high endeavour.

While scientific societies played an important part in the early development of science, today they have become entirely indispensable channels for the dissemination and recording of new knowledge. In common with other learned institutions, many are now encountering financial and other difficulties both in carrying on their existing services and in making the improvements demanded by the present rapid development of science. It should be their policy to maintain a lively and progressive attitude and to discover and fulfil the contemporary requirements of their members. In return it is clearly the duty of scientists to afford the societies not merely financial but also active personal support.

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Atomic energy—threat and promise

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The physical facts upon which the deliberate release of atomic energy is based are now generally familiar. In the present article, Professor Peierls discusses the potentialities of atomic power, particularly for peaceful uses. He argues that all the applications hitherto suggested amount really to doing better, or more cheaply, things that can also be done by other means. Entirely novel applications of atomic energy will doubtless be discovered when the world has grown more used to the immensely powerful tool now at its disposal.

INTRODUCTION

In public discussion of the prospects of atomic energy, the threat to the future of civilization which the atomic bomb represents tends to overshadow the promise of benefits from the constructive applications of atomic power. After the first public announcements on the bomb, exaggerated claims for the possibilities of an impending 'atomic age' appeared, particularly in the popular press, and the reaction to them discredited the whole subject.

Serious thought about the prospects is, in any case, made difficult by the lack of information, due partly to secrecy restrictions and partly to real uncertainties in the physical, chemical, and engineering data.

In the present article I shall endeavour to appraise the positive possibilities as they appear today, and as far as this is possible within the limits of available information. In many instances it will not be possible to give definite answers, but merely to indicate the factors on which the answers depend and the types of problems that have to be solved before the answers can be found.

It does not seem necessary to summarize the physical facts on which atomic energy is based, since by now a number of simple introductions are available (see page 57).

THE ATOMIC BOMB

In discussing the potentialities of atomic energy it would be futile to ignore atomic weapons, not only because they were the first and, up to now, the only important practical application, but because the threat which they represent must always override all imaginable advantages. If there is to be another world war fought with atomic weapons and, as we have to expect, with other new weapons of mass destruction, prospects are so grim that the constructive applications of atomic energy would give us poor comfort. If, on the other hand, international politics were to progress to a point where we felt reasonably confident that there would not be another major war, this would represent such an enormous step forward that the direct benefits would for a long time appear insignificant in comparison.

This problem is essentially political and outside the scope of this article, but it may be appropriate to summarize here the features of the atomic bomb that make it play such an outstanding part. We have often been reminded that the atomic bomb raids were not the most destructive single operations in the past war, nor the ones involving the greatest number of casualties. The essential new feature lies in the comparative cheapness of these weapons, once the necessary scientific and development work has been done, and in their small bulk, which makes it possible to deliver them by a variety of means against which an effective defence and even an adequate warning system seem quite impossible. As a result of this, once stocks of atomic bombs are available, surprise action becomes much easier than with other forms of attack, which require large operational forces.

It is probably not true that atomic bombs in themselves would make a future war much more destructive. Other destructive techniques were perfected during the recent war, and there is no doubt that such weapons as rockets of the V2 type were only just beginning to play their part. Other new developments, like chemical and biological warfare, about which very little has been said in public, share many of the features of atomic bombs. Attention has focused on the atomic bomb because its effect has been demonstrated.

One of the essential features of atomic warfare is that it is bound to result in heavy damage and casualties to all parties (assuming that both sides possess these weapons) and that, while it may be possible to deliver a crippling blow in a very short time, this will not prevent retaliation striking even

the country whose stocks of atomic bombs are superior. Hand in hand with that goes the fact that, while they could destroy a country, atomic bombs could not be used to occupy and hold it. Hence they lend themselves to irresponsible destructive action but not to any calculated aggressive war that is likely to benefit the aggressor.

It is important to stress this feature because it indicates that the destructive nature of atomic weapons may itself be of ultimate benefit if it helps to bring home to everyone the lesson that the use of military force for aggression does not pay.

CONSTRUCTIVE USES OF ATOMIC BOMBS

Supposing the threat of atomic warfare could be eliminated, are there any other uses to which atomic bombs could be put? No definite suggestion has so far been made that can bear examination, but the problem is so new that the possibility should not be ruled out altogether. The use for mining and other similar engineering operations would seem extremely difficult, for three reasons. One is the enormous intensity of the blast action in the immediate neighbourhood of the explosion centre, which leads to a much more thorough destruction than is necessary or desirable. This immediately rules out the use in all those mining operations where one is dealing with a narrow vein of ores. One would probably then find the ores thoroughly mixed up with the surrounding matter, and their recovery would be more difficult than before.

The second difficulty lies in the fact that it is very difficult to use atomic explosions in a controlled way and to limit their effects, since in any use underground the range of the blasting action will depend greatly on the nature of the geological structures, which are hard to explore over a region as large as the likely range of the explosion. In addition, the power of atomic bombs is not exactly predictable and will vary somewhat from one instance to another, depending in most types of design on whether or not a stray neutron happens to initiate a chain reaction before the mechanical assembly of the components is complete. Even if the power of the explosion could be made precisely reproducible there would still remain the difficulty that the precise range in different types of rock or soil could be ascertained only by experimentation (as it is with ordinary mining explosives), and such experimentation covering the necessary variety of conditions would be a prohibitive task.

The third difficulty is that in an underground explosion the greater part of the fission products, with their intense radioactivity, would probably remain on or below the ground and that therefore the affected area would become inaccessible for a very long period. This difficulty did not arise in the past because, for explosions in air, most of the radioactivity is carried up into the upper atmosphere, while in underwater explosions it is reduced fairly rapidly by dilution.

In spite of these difficulties, one could imagine cases in which it is not necessary to limit the range precisely. This applies, for example, to breaking a gap in a mountain range so as to alter the course of a river, or to breaking up an ice-pack that threatens to cause serious obstruction. The danger of radioactivity may not be serious where speedy access to the area is not needed or where one can make sure that rising air will disperse the products.

ATOMIC POWER

Leaving aside the very speculative possibility of utilizing atomic explosions, we are left with atomic chain reactions conducted in a controlled way. Their most obvious use lies in the power they generate. From the point of view of basic physics this problem is completely solved, and there is no difficulty in operating an atomic pile in such a way as to generate heat at whatever rate it can be removed from the pile by a suitable cooling medium. Considerable engineering problems remain, however, of which the most serious is the question of reaching a temperature at which the generation of power becomes economical.

The chief reason for this difficulty is that in all piles constructed with ordinary uranium the reproduction factor, i.e. the number of secondary neutrons available to cause further fission for each primary neutron resulting from the previous fission process, is only slightly larger than unity. The chain reaction can, of course, proceed only if this reproduction factor exceeds unity, and any cause that will reduce it by more than the slight available margin will prevent the pile from operating. Such a cause is represented by the absorption of neutrons in impurities, in the cooling medium, or in materials introduced for structural reasons. Hence if we think of piles made of uranium metal and graphite, like the piles now operating at Hanford in North America, we must not only use uranium and graphite of an extremely high degree of purity, with tolerances for certain impurities of the order of a few parts in a million or better, but the amount of water or other cooling medium used in the pile and the

amount of other materials introduced for structural purposes or for preventing corrosion of the uranium metal must be extremely limited. Because of such limitations the Hanford piles do not permit a temperature-rise that would allow the generation of steam at even a modest pressure. There seems no doubt, however, that a determined attack on the remaining engineering problems will lead to a solution in which the temperature of the pile can be raised considerably. As far as the basic nature of the reaction is concerned, there is no practical limitation to the temperature. There is, in principle, no reason why it should not be taken up to a point where the utilization of the heat by means of steam engines or turbines or any other methods of generating mechanical energy is most favourable. How far this can be carried in practice is as yet unknown, and the higher the temperature the greater the difficulties in protecting the structural components against corrosion or against mechanical distortion. Both problems are accentuated by the presence of intense radiation, which accelerates chemical action because of the high degree of ionization and dislocation of atomic structures that it causes, and which may even reduce mechanical strength.

Some of the problems in the way of high-power piles would be eased if the piles were constructed not of ordinary uranium but of enriched material, obtained either by separation of isotopes or as a result of nuclear transformations carried on in piles of the Hanford type or in the power piles themselves. In this case the active content of the piles is increased, and with it the margin in the reproduction factor. Piles constructed in this way have much more latitude in the use of structural materials and cooling medium, but the corrosion problems remain, and at the same time the piles burn a very much more expensive fuel.

Another difficulty in the operation of all piles is represented by the dangerous radiations, contributed in about equal parts by the neutrons themselves and by the gamma rays resulting from neutron-capture in the pile and from the radioactive fission products. This necessitates heavy protective shields around the piles, and arrangements for doing any adjustments on them by remote control. It also requires arrangements to prevent the escape of radioactive materials by way of the cooling medium into the machinery driven by the pile. Otherwise this machinery would become radioactive and would have to operate inside the radiation shield; it could then not be serviced except by remote control.

Similarly, refuelling of the pile and removal and treatment of depleted fuel have to be carried out by remote control. These obstacles have been overcome in the piles now in operation, but they represent severe limitations in the engineering design.

ADVANTAGES OF ATOMIC POWER

We have seen that, even if not all engineering problems in the way of the production of atomic power have been solved, they at least appear soluble. What will be gained by making atomic power available on a large scale? We shall first consider large stationary power units, used to generate electricity.

The cost of electricity from such stations will depend on the cost of the fuel, the capital charges and running expenses of the pile itself and its auxiliaries, and the cost of generating machinery and distribution. The last item is much the same as for conventional power stations, except that the factors governing the location of atomic power stations are different; this may affect the distribution cost. The pile itself probably represents a much greater capital investment than a boiler plant, though not necessarily a higher running cost. The actual cost is hard to estimate when the design is as yet unknown. Since the pure materials (uranium, graphite, etc.) required for the pile represent a major item, the cost must also depend on the scale on which these are being manufactured, and hence on the overall scale of the atomic power programme.

The cost of the raw material at pre-war market prices is very small compared to that of a corresponding amount of coal. No doubt the applications of atomic energy make uranium a more valuable material, and indeed, because of its military importance, there is presumably no free market for it at all. Even so, quite a considerable rise in the cost of raw material would hardly affect the cost of electricity from such a plant.

These considerations show that, since at present the generating and distribution costs are a large item in the price of electricity, the cost of atomic power is likely to be about the same as for electricity from coal and that, even if we assume the pile to cost no more than a boiler plant and the fuel to cost nothing, the price of electricity would fall by only some 20 or 30 per cent.

A recent official statement by the American authorities confirms these rough estimates, and arrives at a price for electricity that is slightly higher than the current one. A slight increase in the cost of coal at the power station would

equalize the difference. No details were quoted, but it seems likely that a similar estimate for conditions in Great Britain would show a slight balance in favour of atomic power. These figures are not meant to be precise, and further experience may well show a somewhat greater margin on either side.

It follows that we can hardly expect a revolutionary change in the price of electricity. One specific advantage of atomic power is the small bulk of the fuel consumed, which makes the power stations independent of access to railways and waterways. This allows the planning of power stations close to the consumer, and reduces the difficulties of distribution; it also gives more freedom in placing the stations in positions where the low-grade heat that is always a by-product of the generation of power can be used for heating or for industrial purposes.

This specific advantage is of outstanding importance in the case of countries, such as Italy, in which there are no adequate resources of power and where the transportation of coal becomes an important factor. It may even make possible new projects, such as the irrigation of desert areas in which the supply of power would today present prohibitive difficulties.

In addition, atomic power may add to our resources if and when the depletion of known coal deposits, or lack of people who are attracted to mining as a career, limits the supply of coal. At equal cost, it would surely be preferable to employ fewer men in coal mines. It should not be assumed, however, that atomic power stations may in the immediate future reduce the demand for coal. Even disregarding the time still needed for the necessary development work, it will take a long time to build atomic power stations on a sufficient scale to have any effect on world economy. It will take an even longer time to convert to electricity such things as railways, domestic fires, and so on, the conversion of which would become worth while only if the price of coal were to increase relatively to that of electricity. In any case it must, of course, be remembered that there will always remain some need for coal for metallurgical, chemical, and other purposes.

All these considerations are based on the assumption that sufficient amounts of atomic fuel can be found. The next section will deal with the question of their availability.

SUPPLY OF RAW MATERIALS

From the previous section it is clear that the availability of atomic fuel is a vital question for the success of any atomic power project. It would seem an easy task to estimate the accessible deposits of suitable ores and compare them with the expected demand, but there are a number of factors complicating this issue. Firstly, the only large atomic piles that have so far been operated work with ordinary uranium. Since the major constituent of this is uranium 238, which does not undergo fission with the slow neutrons on which these piles operate, it is only the rare constituent uranium 235 which is consumed in this operation. This represents only 0·7 per cent. of the uranium found in nature. In the course of this operation, however, some of the neutrons are captured in uranium 238 and convert it (through the intermediate nucleus, neptunium 239) into plutonium 239. It is well known that this conversion was, in fact, the main object of the Hanford piles. It has been stated that the number ν of secondary neutrons obtained from each fission process is greater than one (otherwise no chain reaction would be possible) but less than three. Of these ν secondary neutrons from each fission, one must in a steady chain reaction be captured in another fissile nucleus so as to maintain the chain reaction, and the remainder $(\nu - 1)$ will either escape from the surface of the pile or be absorbed in one or the other of its constituents. Escape from the surface can be made small by increasing the size of the pile, but there are unavoidable losses due to absorption in the 'moderator,' i.e. the substance used for slowing down neutrons (which in the Hanford piles is graphite), in the cooling medium, and in the necessary structural elements of the pile. The remainder may be available for absorption in uranium 238 or in other suitable materials mixed into the pile for this purpose. This number is less than $\nu - 1$, and from the published figures is therefore certainly less than two. We thus know with certainty that at most two atoms of plutonium will be made for every atom of 235 burned in the pile, and it is also clear that this is a generous upper limit.

If it were possible to run the pile in such a way that this number were greater than one, the amount of plutonium generated would be greater than the amount of 235 burnt up. If the properties of plutonium were similar to those of 235, this would mean that by leaving in the pile an appropriate fraction of the plutonium so made we could in this way make up for the uranium 235 that was burnt, and such a pile could therefore continue operating until the depletion of

uranium 238 reduced the rate of production of plutonium. In these conditions it would therefore be possible to burn not only the uranium 235 but a substantial fraction of the uranium 238.

With our assumptions, the condition for this process is that $\nu - 1$ should exceed one, i.e. that ν should exceed two. There is no guidance from published figures as to whether or not this is the case. Actually we have made the assumption that plutonium is about as efficient a fuel as uranium 235; if it differs appreciably, the critical limit for ν may be somewhat different from two. It will, in any case, be increased by the unavoidable loss of neutrons through absorption in other parts of the pile.

Since, as this process continues, we shall be burning plutonium rather than uranium 235, its success will also depend on the value of ν for the fission of plutonium.

Lastly, it is known that a new fissile material can be made by the bombardment of thorium with neutrons, and that this new material, which is an isotope of uranium of weight 233, may also be suitable for a chain reaction. No evidence is available on the merits of this isotope as an atomic fuel compared with uranium 235 or plutonium, or on the number of neutrons emitted in its fission.

It is, of course, conceivable that there may be similar processes as yet undiscovered starting from other raw materials, but this does not appear very probable.

All the above uncertainties in the data make the position about raw materials quite obscure. If it should turn out that in a pile starting with ordinary uranium the plutonium produced will more than offset the consumption of uranium 235, and also that as the pile turns over to consuming plutonium the amount of plutonium produced is greater than that consumed, it will be possible to utilize most of the atoms of ordinary uranium. On the other hand, if this is not possible the material will become almost useless when a substantial fraction of the 235 has been burnt. There is, therefore, an uncertainty of about a factor 100 in the amount of uranium required to maintain a given power output. Alternatively, the reaction can be conducted in such a way that some of the excess neutrons are not absorbed in uranium 238 but in thorium, and if it should turn out that the production of 233 more than offsets the initial consumption of 235 or plutonium and later on the consumption of 233, when this becomes the major fuel in the pile, it may be possible to run the power stations in a way in which ultimately the fuel is only thorium without a continuing consumption of uranium. This would at once add substantially to the supply of raw materials upon which we can draw.

Quite apart from this uncertainty, the amount of uranium that we can expect to be available is hard to estimate. There are at present only a few known deposits containing uranium ore in sufficient concentration to make its extraction profitable, but, even if further surveys should not lead to the discovery of new important deposits, it is well to remember that uranium is a common element contained in many minerals (such as ordinary granite) in very low concentration. No methods have as yet been worked out that would make the extraction of uranium from such poor ores a feasible operation. The concentration of uranium in some poor ores is, however, larger than, for example, the concentration of gold in most ores that are commercially worked for gold, and it is possible that a chemical process could be found which would effectively make this uranium available. This would open up sufficient quantities of uranium for any power programme that is likely to be needed in the foreseeable future.

Evidently the question whether any particular extraction process will make low-grade ores economically interesting depends on the price at which the fuel would make the production of atomic power compete successfully with those from other fuels. At present the price of the raw uranium is quite a small fraction of the estimated cost of atomic power, and a considerable increase in the cost of mining and extraction could be tolerated without altering the picture substantially. The limit depends on the place in which power plants are contemplated, because of the cost of transportation of coal, and on the likelihood of an increase in the price of coal owing to the exhaustion of suitable deposits, and other factors.

We must conclude that, while the uncertainty in all these facts certainly does not allow us at this stage to feel assured that a sufficient supply of atomic fuel can be obtained, it is equally impossible at present to exclude this possibility. It is certainly of sufficient promise to justify intensive study and development work.

MOBILE POWER AND OTHER SPECIFIC APPLICATIONS

Can atomic piles be made suitable for small units to be used in ships, trains, etc.? There are a number of factors which make the operation of small plants uneconomical. The first is the

critical size. It is known that for each reacting system there is a least size at which chain reaction becomes possible, since for any system of smaller size the number of neutrons lost by leakage from the surface reduces the reproduction factor below the critical limit. In the ordinary pile made of uranium metal and graphite we have already seen that the margin in the reproduction factor is very small. Hence only a small leakage of neutrons can be tolerated, and the least size of plant becomes very substantial. If one desires a power unit with a small power output, the plant will still have to be at least of the critical size and will therefore be very bulky. In addition, the amount of atomic fuel locked up in such a power unit is then very substantial, and the unit therefore represents a relatively large capital investment.

Things are more favourable if one can use concentrated atomic fuel, i.e. either uranium 235 obtained from a separation plant, or plutonium, or possibly uranium 233 from thorium. In the case of these substances the reproduction factor is considerably larger, and this brings the critical size down to quite a convenient magnitude. In fact, it is likely that in practice the size of such a unit would be determined by the requirement of getting in the necessary amount of internal surfaces for heat-extraction purposes. On the other hand, such concentrated fuels are very much more expensive. In the case of uranium 235 this would have to be produced by an isotope separation plant of the type of the plants that produced the material for one variety of atomic bomb, although the degree of separation need not be the same as that suitable for the bomb. Plutonium and uranium 233 are produced in piles, and their cost depends essentially on the considerations referred to in the previous section. If it turns out that a suitable pile can not only regenerate the fissile material necessary to keep the pile in operation, but also leaves something to spare, it might be comparatively easy to get fissile materials as by-products of power production.

Even for piles with enriched fuel, however, there remains the need for protective shielding, and it has been estimated that the minimum weight of such a shield is about a hundred tons. This clearly at once rules out use in cars or trains, but a weight of this order is quite modest if one thinks of its use, for example, in a large ship. In fact, it would appear possible in the case of a ship to use the surrounding water as part of the shield and thereby further reduce the deadweight that has to be carried. Whether atomic ships are a practicable proposition is therefore merely a economic question. In comparing the cost o atomic power with coal or oil one has to bear i mind that ships would have to use concentrate atomic fuel, as it does not seem likely that a powe unit of the size, say, of the Hanford piles woul be suitable for a ship. It is impossible to estimat at the moment the cost of the concentrated fuel On the other hand, it is certainly an advantag that the weight of the fuel consumed during th voyage would be quite negligible, and this factor would be particularly important for long journeys without refuelling.

As regards aeroplanes, the need for a heavy shield is certainly a most serious handicap, and atomic planes cannot be practical unless one increases by a large factor the overall size of the plane and, with it, the size of the runways, etc. Even if one is prepared to do this, one would probably not want to operate the power unit of a plane on low-grade heat, which would necessitate the use of steam engines. The solution of this problem is therefore dependent on raising the temperature in the pile to a level where more modern forms of conversion to mechanical power become possible.

On the other hand, the low weight of the consumed fuel is in this case a most important consideration, and if an atomic plane is possible at all it will have a practically unlimited range without reduction of the carrying capacity.

A particularly interesting problem is that of using atomic energy in rockets for interplanetary travel. If one looks at this problem purely from the point of view of the balance of energy, it is clear that atomic power overcomes the major handicap of other such rockets. The energy necessary to carry a certain amount of ordinary fuel beyond the range of attraction of the earth is greater than the energy obtained by burning the fuel, whereas for atomic fuel it forms a negligible fraction. However, rockets operate on the recoil produced by ejecting the combustion products backwards, and, since the mass of the combustion product is negligible in the case of atomic power, such rockets would have to carry material specially for the purpose of ejecting it. Thereby one loses all the advantage of the low fuel weight, unless it is possible to eject materials at a speed in excess of that of the combustion products in ordinary material. This means that one would have to use atomic power for heating a suitable substance to a temperature higher than the flame temperature in ordinary rockets. Though there is

nothing to prevent this in the basic process of a chain reaction, the engineering difficulties are clearly formidable.

RADIOACTIVE ELEMENTS

To return from speculation to well-established fact, we next consider the uses of radioactive elements produced in piles, either as fission fragments or by the neutron bombardment of almost any substance. These can be used for most of the purposes for which naturally radioactive elements have been used in the past, such as medical therapy and industrial radiology, but they are becoming available in practically unlimited amounts, and with a much greater variety of properties. A doctor can, for example, choose for his treatment a radioactive element of a suitable lifetime and can thus inject it close to the affected spot. The decay of the activity will then limit the total dose. At the same time there is more freedom in the choice of the hardness of the radiation. By choosing a radioactive isotope of a suitable element it may be possible to cause the radioactivity to accumulate in a suitable place in the human body, and this principle has been successfully applied in the United States to the treatment of a rare form of thyroid disease by means of radioactive iodine.

In radiology, gamma rays may for certain purposes be preferable to X-rays because of their greater penetrating power, and because they allow the use of a very compact source which may, for example, be placed inside a small opening insufficient to house an X-ray tube. Atomic piles can produce such sources with intensities greatly in excess of those practicable with radium.

A much more important application, however, lies in the use of radioactive tracers for chemical or biological research. This gives the possibility of labelling certain atoms and recognizing them afterwards, while allowing them to take part in a chemical or biological process in which their history will be precisely the same as that of other atoms of the same element. This allows us to recognize, for example, the exchange of two atoms of the same element between two different molecules, and it allows us to identify the origin of substances in a living body—to see, for example, whether they are taken up as part of the current food intake, or whether they come from deposits of the same substance in other parts of the body. Such tracer methods were already being employed before the war, using radioactive isotopes made in the laboratory by means of cyclotrons or other machines. Atomic piles provide both greater quantities and greater variety.

A further advantage of such tracers is that their radioactivity may make it possible to observe them in the living body, while keeping the intensity of radiation well below the safe tolerance limit. It is immediately evident that this method of studying chemical reactions in the living body is an extremely powerful tool.

Similarly, there are applications of such tracer elements in other fields, notably in engineering research. These possibilities have not yet been adequately explored.

The amounts required for such experiments are usually quite small, so that a pile which, as a power station, has a very modest output can keep a number of laboratories supplied. In the United States such radioactive tracers are already freely available, but their export is prohibited by Act of Congress. In England work is in hand on the construction of a pile for this purpose.

OTHER POSSIBILITIES

All the applications discussed above amount really to doing better, or more cheaply, or more conveniently, things that could also be done by other means. Nobody has so far shown enough foresight to say what completely new uses may be found for atomic energy. Similar reasoning applied to the steam engine or to electricity or to the internal combustion engine, when they were first introduced, would evidently have given a very incomplete picture of their promise. It may well be that the really important applications will not be thought of until the world has got more used to the new possibilities.

However that may be, I hope to have made it clear in this necessarily vague and incomplete report that a great wealth of new possibilities is opened up by atomic power, and that, if we show enough enterprise and determination in exploring them, they are bound to add materially to the resources of the world.

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The Royal Botanic Gardens, Kew

SIR EDWARD SALISBURY

'Kew Gardens' are famous the world over: to the layman as one of the sights of London, and to the botanist, horticulturist, and arboriculturist as their own particular Mecca. The four main divisions of the institution, namely the living collections, the herbarium, the museums, and the research laboratory, together form an unrivalled instrument for the recording and expansion of our knowledge of plants and plant products. Sir Edward Salisbury, the present Director, describes the Gardens and their main service to the study of vegetable life.

The Royal Botanic Gardens at Kew are an institution that, in a typically English way, had its origin in private enterprise. The initiative dates back to some 180 years ago, when Princess Augusta (mother of George III) began to form a botanical collection which the acumen of Sir Joseph Banks quickly raised to the first rank of importance. Even so, the collections declined in the early years of the nineteenth century and might have been lost as a national asset had it not been for the report of Lindley, the first Quain Professor of Botany at University College, London. Now, more than a century later, another Quain Professor has become Director. The Gardens as we see them at the present day owe much of their planned beauty to the first two directors, Sir William and Sir Joseph Hooker. The Hookers were followed in turn by Sir William Thiselton Dyer, Sir David Prain, and Sir Arthur Hill, each of whom effected further improvements.

The extent of the Gardens today is some three hundred acres—a far larger area than the original garden—and it is because a second garden was joined to the first that the plural still persists in the official title. Many of our countrymen in Britain are rightly proud of Kew, but its real value is probably more appreciated, and for better reasons, by our kith and kin overseas than by those at home. The latter too often regard Kew as an especially attractive public park, and though its value as a summer resort amid floral beauties must not be underrated, yet the wider recognition that this aspect is but a by-product of its real function might perhaps induce a greater and more intelligent regard for the specimens it contains.

The number of living species which are here cultivated is quite remarkable, and it is a tribute alike to the horticultural skill of the garden staff and to the adaptability of the plants themselves that even in the open there are to be seen many thousands of species culled from the most diverse regions and soils. In the Temperate House, probably the largest glasshouse in the world, over an eighth of a mile in length, are to be seen the Acacias and Epacrids of Australia and New Zealand; the Camellias of Japan; a wonderful display of Tree Ferns, Rhododendrons from the Himalayas and Java; the marvellous pink blossoms of *Magnolia mollicomata*; and the flamboyant blooms of Tibouchina from tropical America. Or we may walk over to Decimus Burton's masterpiece, the great Palm House, so well proportioned that its great size—more than 360 ft. long and 66 ft. high—is but half realized. Here a collection of Cycadaceae gives us some faint idea of what the vegetation of the earth must have looked like in Jurassic times, when plants of this affinity were an important feature not only in the tropics but elsewhere.

Here too we see the Screw Pines, and tall Palms striving to push through the roof. Or again we go to the Tropical Fern House and see Giant Ferns on the one hand and on the other the puny modern descendants of the giant Lycopods that formed so marked a feature of Coal Measure forests. Then, having thus paid tribute to the outmoded fashions of plant life that achieved their zenith in former epochs, we wander out into the Arboretum, where thousands of species of dicotyledonous and coniferous trees represent the dominant types of the arboreal vegetation of the present day.

All these collections of living plants, comprising more than forty thousand species grouped to please as well as to enlighten, are but a part of the mechanism that Kew provides for the accurate naming of plants and the growth of knowledge of the vegetable kingdom. Indeed, the living collections form a supplement to the Herbarium housed in the extensive buildings to the north of the main entrance, where more than five million specimens are preserved—a vast collection in which the

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FIGURE 1 – *Museum No. III, erected by Sir William Chambers in* 1761.

URE 2 – *The Pagoda, a relic of the Oriental phase* (1761).

FIGURE 3 – *A glimpse of the Cycad collection in the Palm House.*

FIGURE 4 (*above*) – *Rhododendrons and tulips in the Broad*

FIGURE 5 (*left*) – *Part of the Rock Garden.*

FIGURE 6 – *The Palm House, Decimus Burton's masterpiece, erected* 1844–8.

Broad

proportion of types, co-types, and paratypes is incomparably high. For this reason the Kew Herbarium far surpasses in importance any other collection of such a cosmopolitan character in the world. Hence it is that Kew is the taxonomist's Mecca, and systematic botanists from all over the world are, in normal times, to be found carrying out research within its walls. Naturally, the Kew collections are especially rich in types from the British Empire, and Kew has thus been the source of production of a long series of Floras, from the famous *Flora Antarctica* and the Flora of British India, published between 1872 and 1897, which treated of some 14,000 species, to the Flora of tropical West Africa, which appeared just before the recent war. Here too is produced the *Index Kewensis*, in which are enumerated the Latin binomials of all flowering plants, with references to the source of the original description. Every five years a supplement is issued to include all newly described plants in this category. The whole constitutes an indispensable tool for all botanical taxonomists. Much of the knowledge and experience of Kew in respect to the taxonomy of particular regions is embodied in the series of floras already referred to, and in numerous monographs of particular families or genera. The Herbarium with its large library is in fact an extensive taxonomical research institute, where a permanent staff and visiting scientists are continually advancing our knowledge of the world's flora.

The *Kew Bulletin of Miscellaneous Information* is the means of recording much of the more-specialized research that is carried on at Kew alike in the fields of pure taxonomy, plant morphology and anatomy, economic botany, and botanical exploration, and it is a matter for concern that the destruction of the stocks of this periodical by enemy action precludes our meeting the numerous demands for copies that we have received from all over the world.

In the Jodrell Laboratory, research work of an experimental character is carried on, and this laboratory is also the department of the gardens concerned with anatomical investigation. Here has been produced a new taxonomic account of the anatomy of dicotyledonous plants, to be published by the Oxford University Press in the near future. This will embody the information contained in the English edition of Solereder, in preparing which Dr Boodle (late Keeper of the Jodrell Laboratory) played so large a part, together with the mass of information accumulated during the past forty years. It was in this laboratory that the classical physiological experiments of Brown and Escombe were carried out, that D. H. Scott did most of his work on fossil plants, and that during the war the possibilities of rubber production from the dandelion (*Taraxacum kok-saghys*) in English conditions were assayed. Here, too, methods of propagation by growth-promoting substances and taxonomic cytology have been studied. Like the Herbarium, it furnishes accommodation for visiting scientists working on the plant material Kew can so richly provide.

Four museums of Economic Botany in different parts of the Gardens house the extensive collections of plant products. They provide not only an indispensable means of reference for the multitudinous inquiries that come in from all parts of the globe, but act as a valuable source of research material. The vast collection of fibres, timbers, drugs, and food products, both in the raw state and in manufactured form, is here to be found arranged on a taxonomic basis.

Thus the four major divisions of the organization of the Institution, namely the Herbarium, the living collections, the Museums, and the Jodrell Laboratory together constitute a powerful instrument for research and information concerning the identity and characteristics of plants and their products.

But while the living collections are of first importance as a supplement to the *hortus siccus*, they play, and indeed have long played, a most important role as a source for the distribution of economic species throughout the Empire. The part which Kew played in the initiation of plantation rubber and the cinchona industry is too well known to need reiteration. Kew was also responsible for the dissemination of cocoa and oil palm to West Africa, of pineapple to a number of areas, of the nut *Macadamia ternifolia* to Hawaii, and more recently of the oil-producing tree Aleurites to various Dominions and Colonies. These are but a few examples of the extensive plant distribution which has been rendered possible by the skilled use of the Wardian case. In connection with banana-research in the West Indies, Kew functioned not only as a distributing agency but also as a quarantine station. This latter aspect has gained added emphasis with the increased importance of virus diseases, for unless plants carried from one part of the world to another are healthy their distribution may be a menace rather than a service.

The vast numbers of visitors to Kew every year are a testimony to its great popularity as a resort,

and though for many the Gardens are but a beautiful amenity, they provide for many others a permanent horticultural display where newly introduced or rare species can be seen by the botanical student, the research worker, and the professional or amateur grower. The three stout volumes of *Trees and Shrubs Hardy in the British Isles* by W. J. Bean, a former Curator at Kew, is a gardening classic that embodies much of the cultural lore that has been accumulated during the passage of years. Another such is *The Botanical Magazine*, which was started by William Curtis,[1] but for more than a century has been edited at Kew and contains coloured illustrations and descriptions of new or noteworthy species. It will be realized that the cultural experience of more than a hundred years which has been amassed at Kew enables it to serve as an unusually well-equipped training-ground for horticulturists, and many former Kew students now occupy positions of importance the world over. Moreover, the wide range of material which the gardens can furnish is constantly drawn upon for research in many fields of scientific activity.

Almost every post brings requests for such material. It may be to test the active principle of some plant alkaloid, to investigate the chromosome number of a suspected polyploid, or to compare the epidermal characters of a living Cycad with those of a Jurassic prototype. It is needless to say that, owing to limitations of space and staff, Kew cannot attempt to supply educational material in the broader sense, but in so far as its resources are required for genuine research these are placed freely at the disposal of investigators in universities and other recognized institutions of higher learning—as far as is consistent with the proper maintenance of the collections. The intercourse with overseas botanists is now a highly prized tradition, and it is pleasant to record that though wartime conditions diminished this activity they never caused it to cease, and that it is already being resumed.

The original Botanic Garden was only about nine acres in extent and remained little more until shortly after 1840, when, during the first directorship under Sir William Hooker, most of the present land was added. The only substantial extension since that period was the area of thirty-seven acres presented by Queen Victoria. This comprises the Queen's Cottage grounds, which, as they were left with the proviso that they should remain more or less in a wild state, cannot be appropriately used for planting other than native species.

The area thus acquired a century ago seemed ample—hence the lavish expenditure of space on multiplication of the same species in avenues and in other ways. Since that time the vast influx of species, from both the Old World and the New, has, especially so far as trees are concerned, strained the limits of Kew severely, and at the present time an appreciably larger area would be more than welcome, whilst the glasshouses are now far from adequate.

The Palm House took four years to construct and was completed in 1848. The Temperate House was erected some ten years later and, like most of the glasshouses at Kew, is now too small to meet present needs, despite the fact that it occupies about three-quarters of an acre. Both these houses suffered from enemy action during the late war, a large proportion of the glass of the Temperate House being broken when a heavy bomb exploded in the fork of a near-by beech tree. It is a tribute to both the skill and the devotion of the staff that the resultant losses in plants were much smaller than expected. The Orchid Houses, enriched by gifts from the collection of Sir J. Colman, now contain a remarkable collection of orchid species. The remaining houses contain collections of economic species of tropical and temperate ferns and insectivorous plants, whilst for the general public the *Victoria regia* House, where this giant annual species flourishes, is perhaps the greatest attraction after the conservatory devoted to decorative plants.

Out of doors, the 'order beds' provide valuable material for students, while most of the shrubby and arboreal species are also grouped taxonomically. A recent departure from this tradition has been made, in the interests both of efficient culture and of educational value, by the establishment of a chalk garden.

The different parts of Kew exhibit a variety of styles in landscape gardening, but fortunately, as befits a botanical garden especially, the English style, which we owe in considerable degree to the influence of Kent, Sir W. Chambers, and Pope, who lived at Twickenham, is that which preponderates. Thus so far as conditions permit the ideal aimed at is the display of the natural growth and habit of the species concerned, and indeed the motto of Kew might well be 'Science and Beauty.'

[1] See ENDEAVOUR, Jan. 1946.

The Chemical Society (of London) after one hundred years

C. S. GIBSON

As the oldest society of its kind in the world, The Chemical Society (of London) will find no one to quarrel with its proud assumption of the title 'The Chemical Society' *tout court.* For over a hundred years its Officers and Fellows have blazed new trails in the advancement of chemical knowledge, the reputation of the Society ranking second to none among chemists the world over. This year the Society officially celebrates its centenary—the celebrations should have been held in 1941, but were postponed owing to the war. We congratulate the Society on this happy and auspicious occasion, and wish it a long-continued vigorous life.

In 1938 H.M. King George VI became Patron of The Chemical Society (of London), and the Council began to take steps for the celebration of the centenary of the Society in 1941 by appointing Organization and Executive Committees. At the Ninety-eighth Annual Meeting in 1939, Sir Robert Robinson, F.(now P.)R.S., Waynflete Professor in the University of Oxford, became President, and it was hoped that he would preside over the Centenary Celebrations to be held in April 1941, which were to be followed immediately by the Eleventh International Congress of Chemistry.

Such arrangements as had been made by September 1939 had to be put on one side, and, for example, the formation of an Advisory Chemical Research Council was deemed to be far more important in the national interest than any further immediate consideration of arrangements for the celebration of the centenary of even the oldest chemical society in the world.[1] Sir Robert Robinson was, indeed, the President at the Hundredth Annual Meeting in direct line of succession to Thomas Graham, F.R.S., President in 1841. In the Centenary Presidential Address, Sir Robert Robinson, after recalling some of the earliest details of the Society and the ever-to-be-remembered services to chemical science rendered by Thomas Graham and Robert Warington, the first Honorary Secretary, as the real founders of The Chemical Society,[2] made the following statement:

> The present is no time for festive occasions, for reunions with our distinguished Honorary Fellows, for international intellectual co-operation generally, and certainly not for an organized scientific congress. Therefore the Council has decided to postpone our Centenary Celebrations, which must be compounded of all these elements after the war. This decision has no negative qualities but is a positive affirmation of our intention to organize as soon as possible an occasion worthy of the Society's splendid record and high position among the academies of the world.

Professor J. C. Philip, F.R.S. (Honorary Secretary 1913–24, Councillor for nine years, Chairman of the Bureau of Chemical Abstracts for the first nine years, 1923–32), succeeded Sir Robert Robinson as President. Few have served the Society more faithfully and efficiently than Professor Philip, and his death after only four months as President was a severe loss. He had undertaken the writing of the Centenary History of the Society; this will be completed by Professor T. S. Moore, who, as Honorary Secretary and Chairman of the Publication Committee, has already placed the Society greatly in his debt. As President, Professor Philip was succeeded by Dr W. H. Mills, F.R.S. (Cambridge). It fell to the next President, Professor W. N. Haworth, F.R.S. and Nobel Laureate (Birmingham), to

[1] Justus von Liebig's personal inspiration played a substantial part in the founding of The Chemical Society; and it is significant that the German Chemical Society was founded in 1866, the year after the return to Germany of A. W. von Hofmann, F.R.S. (President, 1861–3) from this country. The Chemical Societies in other countries were founded as follows: France (1857), Russia (1868), America (1876).

[2] The Society was formally constituted as 'The Chemical Society of London' on 30th March, 1841. The designation was changed to 'The Chemical Society' when the Royal Charter was granted in 1848. Nevertheless, according to the records, the Jubilee of 'The Chemical Society of London' was celebrated on 24–25th February, 1891, under the Presidency of Dr W. J. Russell, F.R.S. Among the names of those present at the Jubilee Banquet is that of Mr W. P. Wynne. Happily, Professor W. P. Wynne, F.R.S., is still a Fellow of the Society, to which he has rendered most notable service as Honorary Secretary, Editor, Councillor, and President (1923–5).

lead the Society through the last year of the war period and for one year during the aftermath. Professor (now Sir Norman) Haworth, with his Honorary Officers and Council, although occupied with many difficult problems confronting the Society, began at once to continue the preparations for the celebration of the Centenary, which he announced would be held in London in July 1947, and would be followed there by the Eleventh International Congress of Chemistry.

The celebration of the Centenary of the Society thus falls in the second year of office of the present and fifty-sixth President, Professor C. N. Hinshelwood, F.R.S., Dr Lee's Professor of Chemistry in the University of Oxford. Sir Robert Robinson became President of the Royal Society in November 1945, and is, after Sir William Crookes, O.M., D.Sc., F.R.S. (President 1887–9), the second Past-President of The Chemical Society to assume the most important office in British science.

The Chemical Society was inaugurated in the rooms of the Royal Society of Arts, and for nearly eight years continued its meetings there. After the Society had been granted its Royal Charter the Council decided that the possession of its own rooms would be more in keeping with its newly acquired dignity. From then until 1857 the Society had its rooms at various addresses, at none of which did it remain as long as at the Royal Society of Arts. There are indications that The Chemical Society in those days quickly ceased to be popular with its landlords, because the Fellows making communications persisted in carrying out experiments, frequently attended by the emission of divers odours, in inadequately ventilated rooms. In 1857 The Chemical Society, with the help of the Royal Society, was allotted by the Government a meeting-room and a library room (furnished by the private subscription of the Fellows) in Old Burlington House. The present apartments in (New) Burlington House, built by the Government to accommodate the Royal Academy, the Royal Society, and certain chartered scientific societies, were allotted to The Chemical Society in 1873–4. This accommodation has not been extended for more than seventy years.

The Fellows of The Chemical Society are proud of their home—it houses so many treasures, busts, medals, and pictures illustrative of progress in chemistry and of chemists in many parts of the world. At the same time they have recognized its painful inadequacy for many years. The Library and its annexe on the top floor have had to be modified to provide for the largest chemical library in Britain. In 1873–4 the library consisted of some three thousand volumes, whereas new accommodation has had to be contrived for some fifty thousand volumes. Every room in the building with the exception of the meeting-room —and that may have to be pressed into service— has had to be fitted with shelves and racks, and in some places the latter are so close together that it is difficult to move between them. Literally every inch of space is used for the continually growing collection of books and periodicals. Part of the Society's collection of its own periodicals is stored in various places outside. The accommodation may have been adequate for the 733 Fellows in 1874, but the membership is now over seven thousand, and the Library is also used by members of other societies.

On the first floor is the meeting-room, which accommodates 157 persons. As one may suspect, it is often totally inadequate for the meetings of The Chemical Society and of other societies which have met there for many years. The room has a certain dignity. Behind the demonstration table is the presidential chair, bearing the arms of the Society. On the wall above the presidential chair is the unique painting of Thomas Graham, the honoured first President.[1] On the walls are portraits of all the past Presidents, but unfortunately there is now insufficient space for them to be displayed worthily.

When the Society is in session, the mace is placed before the President or his deputy. The mace was presented to the Society in 1930 by Mr A. H. Hooker. After their election, Fellows are formally admitted at all Ordinary Scientific Meetings and sign the Obligation Book, which contains the signatures of all formally admitted Fellows since the foundation of the Society. The earliest signatures are those of Robert Warington and Thomas Graham.

By the entrance to the meeting-room is the 1914–18 War Memorial to Lt.-Col. E. F. Harrison, C.M.G., and to the twenty-nine other Fellows who died on service. Col. Harrison rendered conspicuous service to the nation by his intense, self-sacrificing energy and his wonderful success in equipping the troops with protection against

[1] This portrait was painted in 1931 from a daguerreotype (in the possession of Dr Alexander Scott, F.R.S., President 1915–17). The artist (Mr W. A. Budd) experienced no difficulty in depicting faithfully the features of Graham; he was, however, anxious to have a model for the rest of the picture. Professor G. A. R. Kon, F.R.S., was the suitably dressed model.

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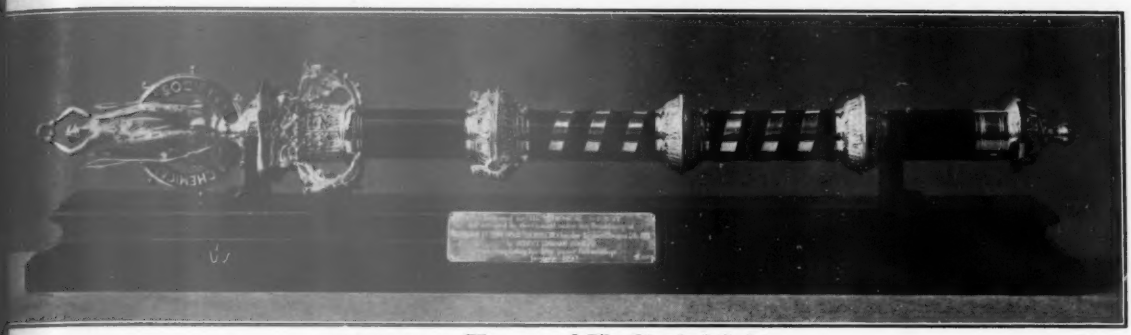


FIGURE 1 – *The mace of The Chemical Society.*

FIGURE 2 – *Professor W. H. Perkin, M.A., Sc.D., LL.D., F.R.S. President* 1913–15.

IGURE 3 – *Professor C. N. Hinshelwood, M.A., Sc.D., .R.S. President* 1946–

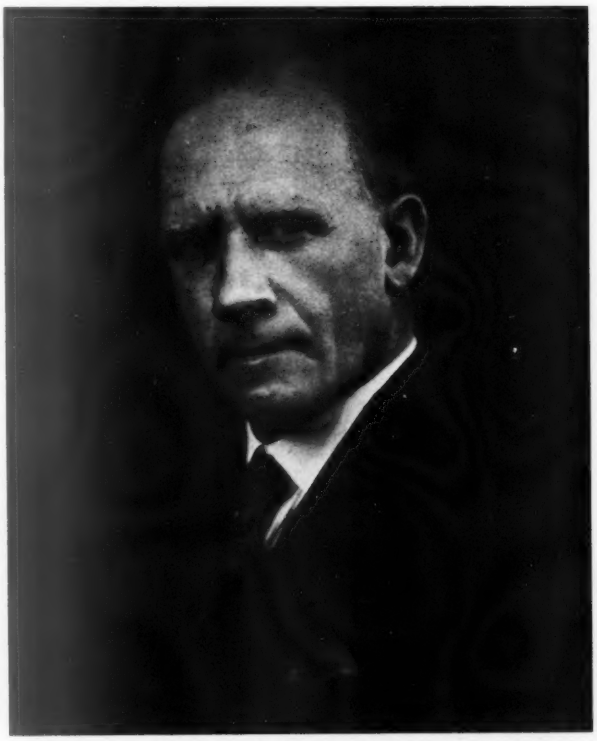
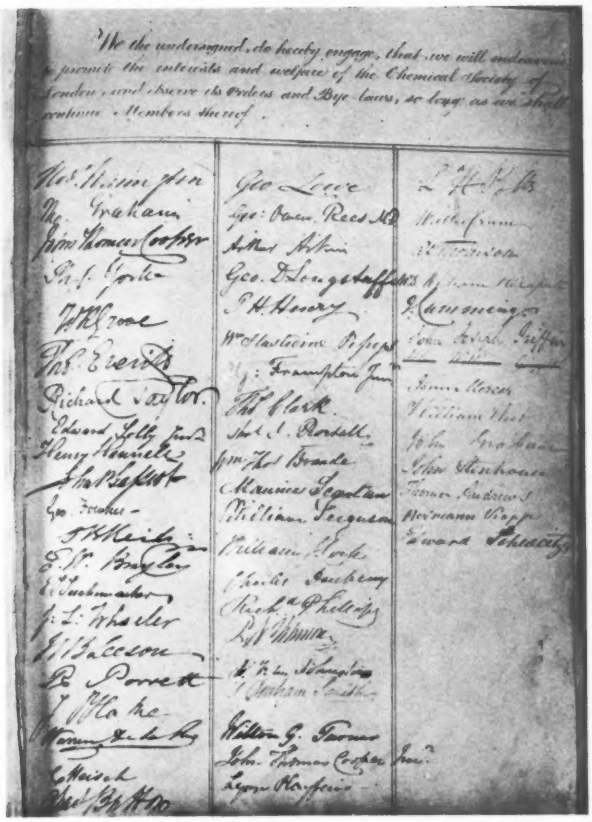


FIGURE 4 – *Professor Sir Robert Robinson, M.A., D.Sc., LL.D., P.R.S. President* 1939–41.



We the undersigned, do hereby engage, that we will endeavour to promote the interests and welfare of the Chemical Society of London, and observe its Orders and Bye-laws, so long as we shall continue Members thereof.

Robt. Warington
Mr. Graham
John Thomas Cooper
Prof. Forbes
J. W. Groves
Prof. Everitt
Richard Taylor
Edward Solly Jun.
Henry Daniell
Thos. Redwood
Geo. Fownes
F. W. Rudge
E. V. Bayley
Jno. Bachhouse
J. L. Wheeler
E. J. Jacobson
R. Porrett
J. Wilkie
Wm. Allen Miller
Chas. Heisch

Geo. Lowe
Sigo: Brev. Rees M.D.
Alfred Arkin
Geo. D. Longstaff
P. H. Henry
Wm. Blackburn Bishop
J. Frampton Jun.
Thos. Clark
Thos. S. Pardell
Jno. Thos. Brande
Maurice Seguier
William Seguier
William Cooke
Charles Sanderson
Nicholas Phillips
R. W. Thwaites
A. F. de Schmidius
T. Graham Smith
Walter G. Turner
John Thomas Cooper Jun.
Lyon Playfair

FIGURE 5 – *The first page of the Obligation Book, bearing as its first signatures the names of Robert Warington and Thomas Graham.*

FIGURE 6 – *Thomas Graham, M.A., D.C.L., F.R. President* 1841–3, 1845–7. *(By courtesy of the Science Museum)*

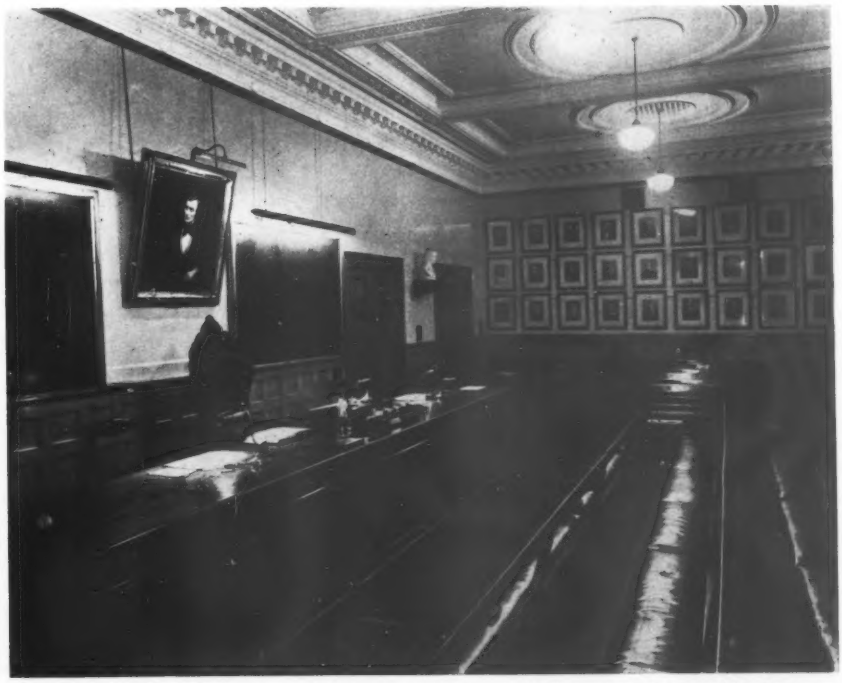


FIGURE 7 – *The lecture room, with portrait of Thomas Graham above the President's chair.*

F.R.
ce Museum

poison gas. The cost of this memorial was defrayed from a privately subscribed fund of which part was used as a trust to establish the Harrison Memorial Prize of the value of £150. This is awarded every three years on the recommendation of a Committee composed of the Presidents of the Chemical Society, the Society of Chemical Industry, the Pharmaceutical Society, and the Royal Institute of Chemistry to the chemist, man or woman, not over thirty years of age, who shall have made the most meritorious contribution to chemical science during the previous five years. The first award was made in 1924 to Dr C. R. Harington, F.R.S.

The General Secretary's room was formerly the laboratory. On the ground floor are the rooms for the Honorary Officers and for Council Meetings. Apart from their use as part of the Library, these rooms, like the meeting-room, are used for office and editorial purposes whenever they can be spared. This very brief description hardly does justice to the home of The Chemical Society, which by the success of the work the Society has accomplished for the science has now become far too small.

Special lectures have been a feature of the proceedings of the Society since its inauguration. The Faraday Lectureship (1868), and the more recently endowed Hugo Müller, Pedler, and Liversidge Lectureships held by distinguished British and foreign chemists, provide valuable accounts of the most important developments in chemical science during the last eighty years.

In 1920 women were admitted to the Fellowship on the same terms as men. This change, somewhat heatedly contested, was followed by increasing the facilities to Fellows not resident in London. Regional representation of Fellows on the Council was instituted, alternate Annual Meetings are held outside London, and special and endowed lectures are delivered in provincial centres. Local representatives keep the Fellows in their respective districts informed of the Society's activities, and co-operate with other chemical organizations in the holding of joint meetings, discussions, and lectures.

From its foundation the Society has concerned itself with the publication not only of its own original contributions and lectures in its world-famous *Transactions* or *Journal*, but of abstracts of papers appearing in other journals. At first only British journals were abstracted, but in 1871 the abstracting service was extended, and from 1873 the abstracts were separated from what up to 1925 were styled *Transactions* and then became the *Journal*. In 1882 the Society of Chemical Industry began the publication of Abstracts of Applied Chemistry Papers. In 1923 the Bureau of Chemical Abstracts was started as a joint committee of The Chemical Society and the Society of Chemical Industry, concerned with the publication of *Abstracts A* (Pure Chemistry) and *Abstracts B* (Applied Chemistry). This first essay in co-operation between chemical societies has been an unqualified success. The pioneer work in the formation of the Bureau was carried out by Professor J. C. Philip, F.R.S., the first Chairman. The present Chairman is Dr L. H. Lampitt, President of the Society of Chemical Industry and *ex officio* member of the Council of the Chemical Society. It is now the Bureau of Abstracts, and is supported by The Chemical Society, the Society of Chemical Industry, the Physiological Society, the Biochemical Society, the Anatomical Society, and the Society for Experimental Biology. It is the largest and most important scientific abstracting organization in Britain.

The Society has published *Annual Reports on the Progress of Chemistry* since 1904, and can be justifiably proud of their success and high reputation among chemical publications. Publication of these Reports has been uninterrupted even during the two world wars, and important extension by the additional publication of review articles is now fully planned.

Co-operation between societies and organizations interested in the progress of the various branches of chemistry has been prominent, especially since the end of the 1914–18 war. In this movement The Chemical Society has always taken a prominent share. Even before the formation of the Bureau, The Chemical Society made its valuable library available to members of other societies. This co-operation of The Chemical Society with the Society of Chemical Industry and the Royal Institute of Chemistry has been greatly advanced by the establishment in 1935 of the Chemical Council. This consists of twenty members representing the three societies and the Association of British Chemical Manufacturers, which has helped The Chemical Society financially and in other ways for many years. Professor E. K. Rideal is the Chairman, and Mr F. P. Dunn, Hon. Treasurer of The Chemical Society since 1938, to whom The Chemical Society owes so much, has placed the Society further in his debt by acting as Vice-Chairman of the Chemical Council.

Each constituent of the Chemical Council

retains its own individuality. It has established a Joint Library Committee with eight contributing organizations. Under the Chairmanship of Mr Dunn it has effected economies and increased efficiency in the production and distribution of the publications of The Chemical Society and the Society of Chemical Industry. Its system of joint membership of the three chartered organizations is in operation, and this has resulted in a marked increase in the Fellowship of The Chemical Society.

Since 1919 the establishment of Chemistry House, in which The Chemical Society will have an honoured place, has been the object of many efforts. The fulfilment of this project has now been assumed by the Chemical Council. If the Chemical Council is as successful in this as it has been and is in its other work—and there have already been generous benefactors—then The Chemical Society and its library will have in a reasonable time the accommodation they have so greatly needed and deserved for many years.

The Fellows of The Chemical Society can be rightly proud of the record of work accomplished by their Society for the extension of chemical knowledge during one hundred years, and of the Society's world-wide reputation. The future presents even greater opportunities than in the past for the work of the Society, and although they are conscious of many difficulties to be surmounted, its Fellows will by the quality of their investigations still further enhance its reputation.

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PAPER RESTRICTION

As a result of the shortage of power for industrial purposes in Great Britain, paper mills have been unable to maintain their normal production. A temporary reduction in the size of ENDEAVOUR will therefore have to be made, and each of the next two issues will consist of fewer pages than usual.

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Some physical instruments used in medicine

DAVID S. EVANS

Chemistry has always found manifold applications in medicine, and was indeed, in the days of iatrochemistry, merely the physician's Abigail. At the present time chemotherapy basks in the glory of such discoveries as penicillin, the sulphonamide drugs, and paludrine. The applications of physics to medicine have so far lagged behind, except in such cases as the use of X-rays and radioactivity in diagnosis and treatment. The many recent advances, however, leave no doubt that physicotherapy has as bright a future as chemotherapy.

The use of X-rays and radioactivity in diagnosis and treatment represents one of the most striking ways in which medicine has made use of physical discovery. So successful indeed, have researches of this character become that an important feature of the relation between medicine and physics tends to be obscured. In spite of the tremendous successes of physics, and in spite of the valuable contributions which physics has made to medicine in the field of X-rays and radium, and in nerve physiology, the general contribution of physics to medicine is far smaller than it might be, and there are many valuable links between the two sciences waiting to be forged.

This is a surprising conclusion in view of the earlier history of the relations between them. Before the differentiation of the sciences, the links were close. Gilbert, the author of a famous treatise on magnetism, was Queen Elizabeth's physician; Copernicus was, at least ostensibly, a physician as well as a priest and an astronomer. Even much later, Thomas Young, known to physicists for his work on light waves, was a physician by training. von Helmholtz had his first education in medicine, and the early conclusions on the conservation of energy were based on physiological experiments.

It seems as if the division between the two sciences was a temporary one only, and now the gap is being closed. As medical men require for diagnosis a more and more detailed investigation of their patients it is inevitable that physical problems of diagnosis should come to occupy a larger place in their thoughts. As medicine arms itself with more and more complex instruments for diagnosis and treatment, so it meets more and more frequently physical problems of design beyond the capacity of the medical specialist to solve. Co-operation between the two sciences was greatly encouraged by the late war, when the medical profession found itself faced with problems of casualties and disease of an entirely new order of magnitude, and in the solution of some of them sought the aid of the physicist.

It is not unfruitful to begin the discussion with a consideration of the differences in viewpoint between the physicist and the medical man. On the one hand, the physicist is accustomed to the study of situations involving rather few variables: his experimental conditions are fairly accurately reproducible, and his interpretation of results has a mathematical exactness and niceness. If he is a mathematician as well, he will notice in himself a tendency to believe that he has said all that is worth saying about a problem once he has cast it into mathematical terms, and may even exhibit a dogged determination to defend his mathematical deductions as enshrining the whole truth.

The medical man, on the other hand, shares with his colleagues in the biological sciences all the difficulties consequent upon large individual variations in his material: his primary aim is to diagnose and cure, and here he is faced with a situation embodying an enormous number of factors which defy numerical definition. He tends, and rightly so, to rely on a general assessment of a complex picture in which many of the features have indefinite and almost imponderable qualities which can be judged only by experience.

This attitude indicates the medical problems which can be profitably studied by the physicist. He must, throughout, be guided by his medical colleagues and must not attempt to dominate the situation. The services which he can render are, firstly, to assist diagnosis by providing means for more accurate assessment of physical symptoms, so delineating more firmly part of the general clinical picture. Secondly, he can devote his

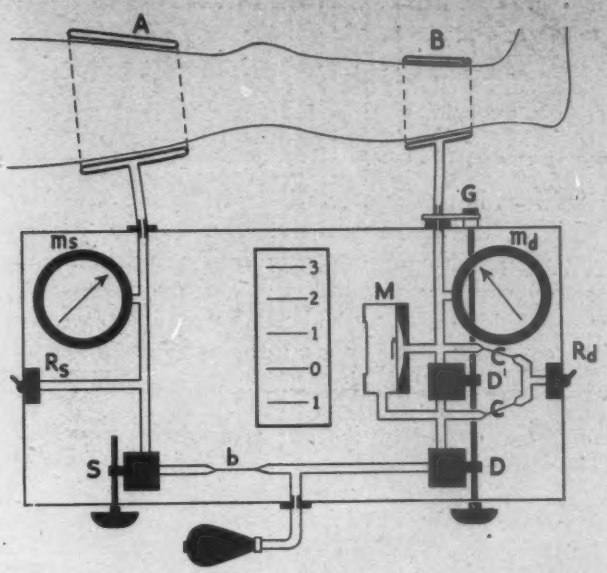

FIGURE 1 – *Circuit of blood-pressure indicator.*
(*Reproduced from the* British Journal of Anaesthesia.)

M = *Membrane manometer.*
m_s, m_d = *Aneroid manometer.*
D' = *By-pass tap.*
D = *Inflation tap, linked to* D'.
C–C = *Capillary.*
R_d, R_s = *Release valves.*
S = *Systolic circuit tap.*
b = *Capillary.*
G = *Safety gate.*

attention to methods of physical clinical treatment and, by physical investigation, render them more precise and more readily controllable.

A third feature of the relationship between the two sciences must be mentioned. As a result of his attempts to aid diagnosis the physicist may provide the medical man with some new instrument: this must be not only reliable in its readings but very robust and easy to operate. A device which is so delicate that it cannot withstand the hazards of use in general medical work, which often needs servicing, or which is so difficult to operate that the practitioner would be better occupied in giving his attention directly to the patient, will soon be discarded. Better by far to produce a less accurate device which can be operated by the turn of a switch and which will survive—for example in military use—a fall from a lorry [1].

Two examples of the work done by the writer in collaboration with Dr K. Mendelssohn will illustrate the practical application of these principles. The first problem was to devise an instrument for the measurement of blood-pressure, preferably by a continuous indication.

The medical background of this problem is as follows. A fall in blood-pressure is one of the earliest signs of the onset of shock in patients in the operating theatre. In casualties a low blood-pressure is a possible indication of a state of shock, although the difficulty here is that the normal blood-pressure even of healthy persons shows a wide variation. As an aid to the anaesthetist, however, who is responsible for keeping the patient in the operating theatre in good shape, the completest possible knowledge of the blood-pressure variations is of the first importance.

The pressure in an artery is not constant, but varies cyclically with the action of the heart. The standard medical method of specifying the blood-pressure is by the maximum and minimum pressures attained during each cycle, these being known as systolic and diastolic pressure respectively. The difference between the two is called the pulse pressure, and it is possible that this quantity represents the best index of the circulatory state of the patient.

The ordinary method of determining systolic and diastolic pressures is by the aid of a rubber cuff which is bound round the arm and can be inflated to any desired pressure, the pressure being read on a mercury or aneroid manometer. A stethoscope is applied to the brachial artery distal to the cuff, and the sounds heard in this at different cuff pressures form the basis of the estimation of the required pressures. Roughly the procedure is as follows. It is assumed that the pressure in the cuff is transmitted through the tissue to the artery. If, therefore, the cuff pressure be greater than systolic, the artery beneath the cuff will be occluded, no blood will flow past the obstruction, and no pulse sounds will be heard in the stethoscope. If the cuff pressure is lowered to a value intermediate

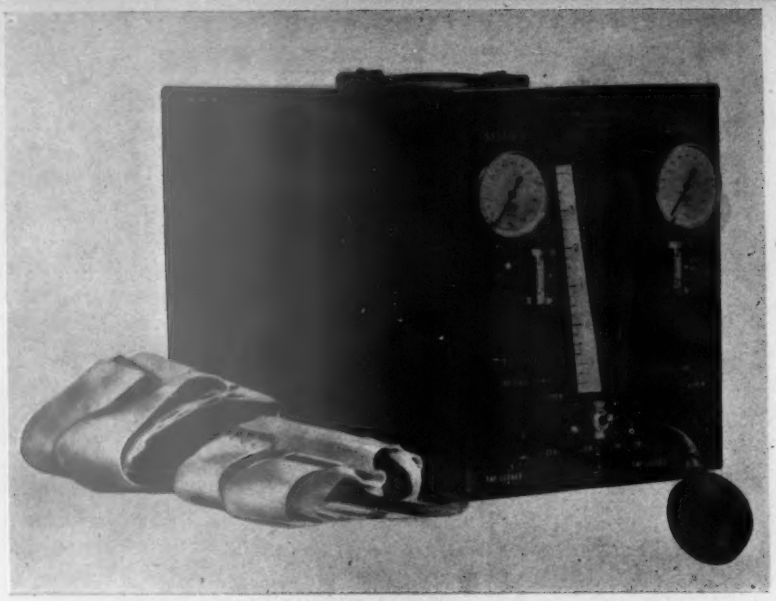

FIGURE 2 – *Blood-pressure indicator. The pulsations are shown by the movement of a light-spot on the central scale.*

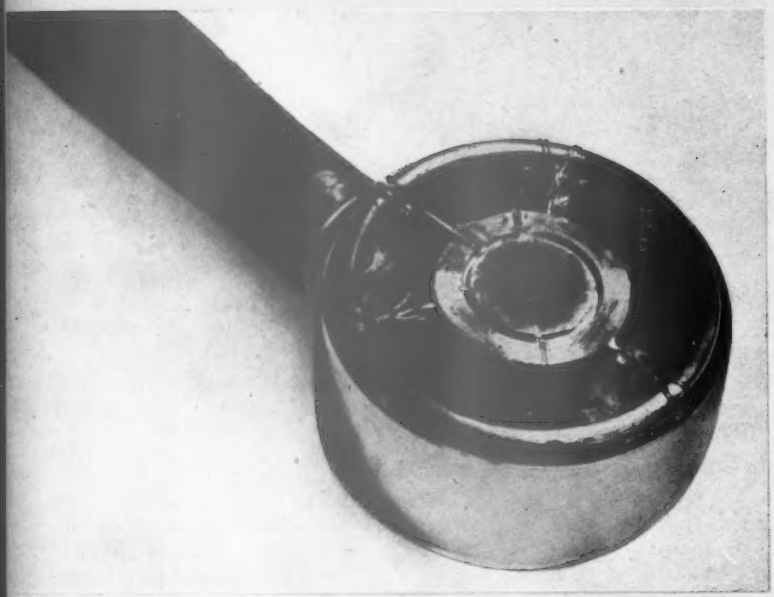

FIGURE 3 – *Radiation flux-meter. The upper receiver disk, supported on a copper block, is visible. The lower disk faces the water jacket forming the base of the instrument. Water tubes and electrical leads pass through the handle.*

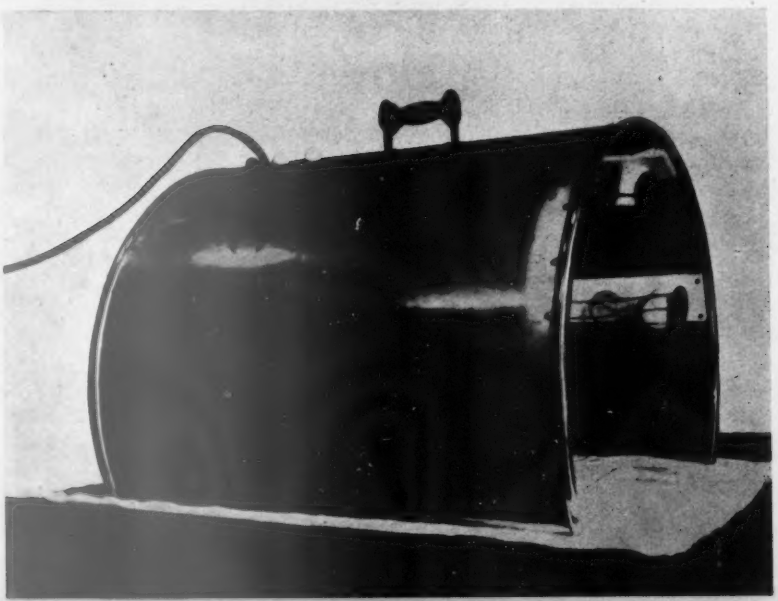

FIGURE 4 – *Radiant heat cradle. (For experimental purposes the inside surface of the metal horseshoe has been blackened.)*

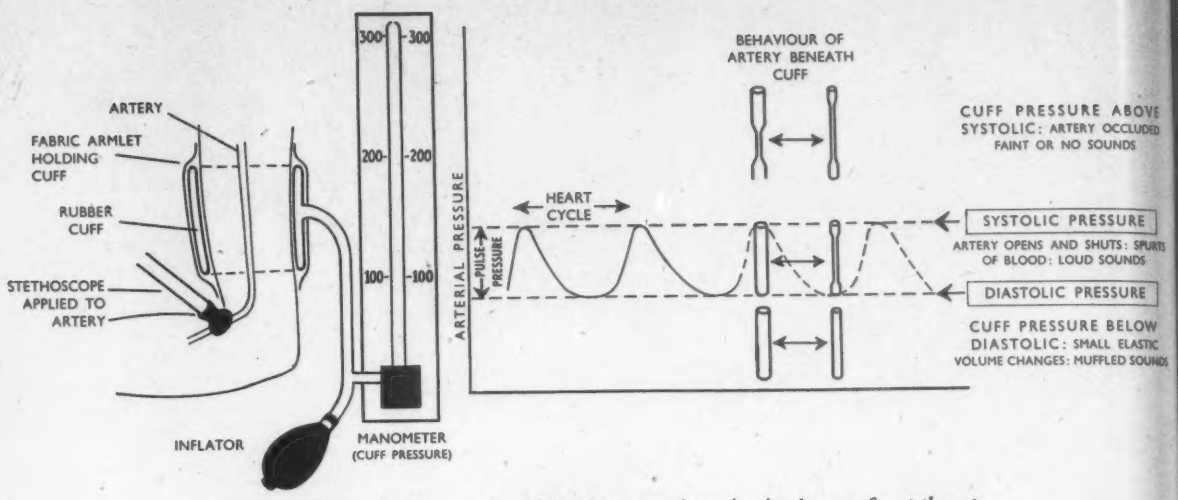

FIGURE 5 – *Schematic representation of blood-pressure determination by use of a stethoscope.*

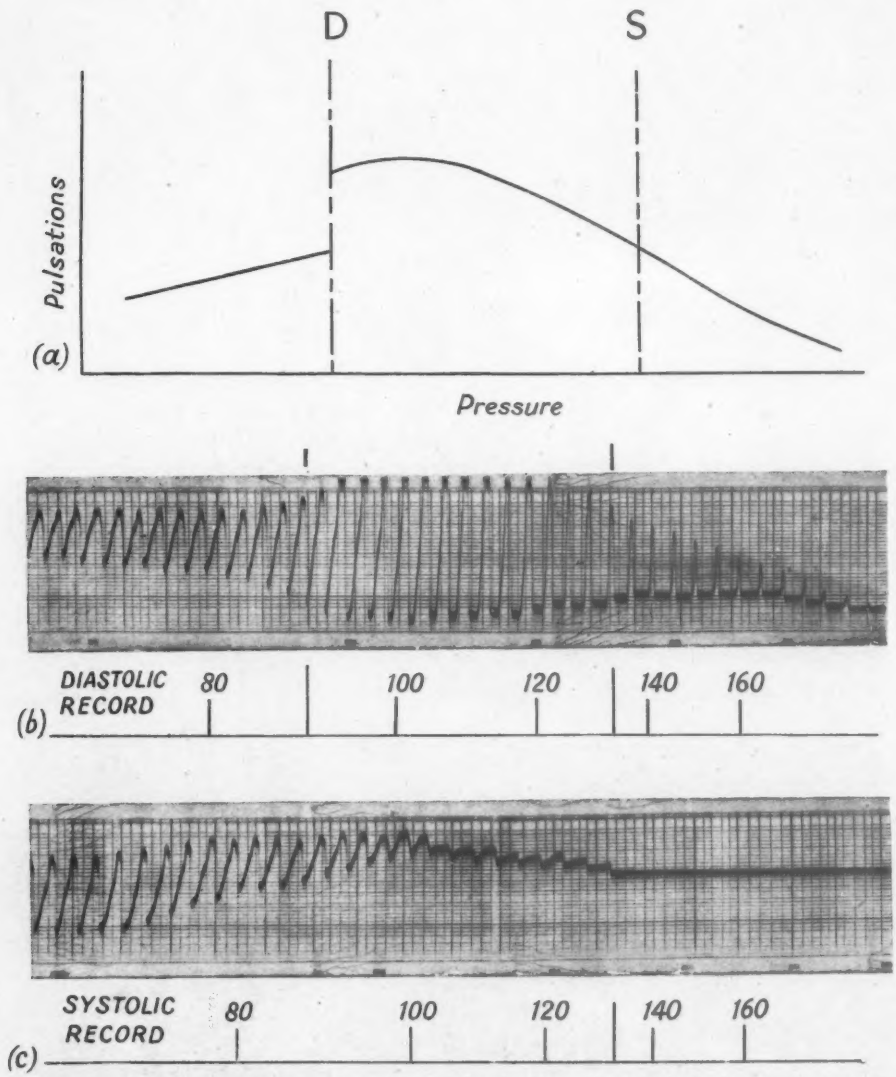

FIGURE 6 – *Theoretical curve (a) and recorded pulsations (b) and (c), in detector circuit of the blood-pressure indicator.* (*Reproduced from the* British Journal of Anaesthesia.)

between systolic and diastolic, the artery will be patent during part of each heart cycle, and loud sounds will be heard in the stethoscope. The cuff pressure at which the sounds start is taken as systolic.

When the cuff pressure is below diastolic, then throughout the heart cycle the internal arterial pressure exceeds the external, the blood-flow is continuous, and faint, muffled sounds are heard. The cuff pressure at which the sounds become muffled is taken as the diastolic pressure (figure 5). The disadvantages of this method are, firstly, that it requires considerable skill accurately to discriminate the sounds, which vary considerably from patient to patient. In a few cases, for example, the muffling of the sounds at diastolic pressure does not take place at all. Secondly, if the work is being carried out under war conditions there may be sufficient noise to drown the sounds altogether. In the operating theatre blood-pressure determinations are carried out by the anaesthetist, using a tambour strapped to the arm of the patient, and this is usually completely inaccessible under sterile drapes. The manipulations of the surgeon may prevent the anaesthetist from securing an uninterrupted hearing of the sounds, or may even displace the tambour, which can never be held in place with the same security as a cuff surrounding the limb, and the anaesthetist may then be left with no means at all of making blood-pressure determinations. In addition, the auditory method is discontinuous, and each determination requires, for the moment, the full attention of the anaesthetist. At the same time, the touch-and-go periods when the anaesthetist has most need of a guide to his patient's condition are precisely those when he is most occupied with restorative measures such as blood-transfusion. Finally, the auditory method can be used only on the arms, and, even if these are not involved in the operation, they are often needed for blood-transfusion, continuous intravenous anaesthetics, and so on.

In order to replace the auditory by a visual indication a suitable detector unit had to be devised. In its final form this consisted (figure 1, right side) of an ordinary cuff *B* connected to a differential membrane manometer *M* having a very sensitive diaphragm, the movements of which are shown by means of a light-beam and scale. The cuff is connected directly to one chamber of the manometer; the two chambers are connected by a capillary *C*. The effect of this arrangement is that rapid pressure-changes are conducted into the first chamber and produce movements of the membrane but are baffled by the capillary; slow pressure changes such as those due to changes in the fluid content of the limb are transmitted, and the mean pressure in the two chambers remains the same. This arrangement allows the use of a membrane giving a full-scale deflection for a pressure difference of a few millimetres of water, such as is produced in the cuff by the arterial volume changes. The system has the advantage that it is entirely pneumatic, and thus the instrument is independent of electric mains.

The nature of the response of this detector unit to arterial pulsations at different cuff pressures is as follows. If the cuff pressure is above systolic, small pulsations are seen; these are due to the impact of the pulse wave on the upper end of the occluded section of artery. Below systolic pressure the artery is patent during a part of each heart cycle, and large pulsations are seen, corresponding to the large volume change from complete occlusion to complete patency. Below diastolic pressure the pulsations are small, and correspond to the small volume changes due to the elastic response of the artery to the pressure changes within it. A closer analysis shows that the transition at diastolic pressure is sharp and forms a good criterion for the determination of diastolic pressure: at systolic pressure there is no sharp change which might be used as a criterion (figure 6).

For the determination of systolic pressure a second cuff *A* is therefore employed, placed proximal to the first. The first cuff and its membrane manometer are employed as a detector unit, and this circuit is inflated to a moderate pressure below diastolic. If now the second, proximal, cuff be inflated above systolic pressure the detector unit will show no pulsations: these will start suddenly when the pressure in the proximal cuff is allowed to fall through systolic pressure (figure 6, systolic record).

A third use of the instrument, which appears to be new, is the possibility of using the distal cuff alone for the indication of pulse pressure (systolic minus diastolic pressure), for the theoretical analysis suggested that the size of pulsations observed when the distal cuff was inflated to a constant pressure below diastolic should be proportional to the pulse pressure. In touch-and-go periods it is therefore possible for the anaesthetist to set the machine to record pulse pressures and to follow them visually while he applies his restorative measures.

The apparatus in its final form is shown in figure 2. The design involved a number of mechanical problems, such as the provision of a

type of totally enclosed, leak-proof tap, and automatic safety devices for the protection of the membrane. The machine has proved robust and has shown itself capable of a number of uses not originally envisaged. For example, it can be used for blood-pressure measurement in the leg, which is not possible by the auditory method. It is applicable to the detection of circulatory abnormalities and to the investigation of rapid physiological changes in the circulation under various experimental conditions. Other developments included a model adapted for photographic recording, and, for the Industrial Health Research Board, a model for recording blood-pressure in the temporal artery while all the limbs were in use [2], [3], [4].

The second problem, drawn from physiotherapy—a particularly fruitful field for physical investigation— concerns the application of infra-red radiation for medical purposes. It is a curious fact that, in sharp contrast to X-rays and gamma rays, the field of medical application of infra-red rays has not been very extensively investigated. Signal exceptions are provided by the researches of such workers as Mayneord and his collaborators [5], and the Medical Research Council has recently established a Committee on Non-ionizing Radiation, which should quickly remedy remaining deficiencies. The reason for this state of affairs is probably to be sought in the differences in physiological action between short-wave and long-wave radiations. In the case of the short waves the most obvious effects are due to specific quantum changes produced in the tissues: these are proportional to the intensity of radiation and often take some time to become fully apparent, so that careful control of dosage is essential. Infra-red radiation, on the other hand, is all in wavelengths so great that the quanta are insufficiently energetic to produce specific reactions, and the only effect appears to be a heating of the tissues, which is noticed almost at once by the patient and can be controlled by the physician. On the other hand, there is a vast difference in scale of the energy used in treatment. In a single treatment, infra-red radiation of a total energy of as much as 20,000 calories may be administered, and doses of this magnitude require careful control, since they approach those capable of causing severe burns, and even of disturbing the general heat-elimination processes of the body.

The specific problem which introduced us to this field arose out of burns caused by a piece of medical apparatus known as a radiant heat or anti-shock cradle (figure 4), which consists simply of a horseshoe-shaped metal sheet fitted on its inner surface with a number of electric light bulbs. This device is placed over the patient and switched on, the object being to keep him warm and to delay the onset of shock. The actual conditions of treatment vary a good deal. Usually the cradle is draped with blankets; sometimes the patient is also wrapped in blankets; sometimes he is treated naked.

The first instruments used in the investigations consisted of various forms of disk receiver forming one junction of a thermocouple, and it soon became clear that a serious time-effect was involved [6]. Evidently the original intention of the metal horseshoe had been to serve as a reflector of radiation, but its real function turned out to be quite different. It actually absorbed a considerable proportion of the radiation, and after an hour or so acquired a fairly high temperature and began to act as a secondary radiator, the area of which was so large that it eventually contributed twice as much as the lamps themselves to the radiation received by the patient. The danger was, therefore, that even if some measuring device were used at the beginning of treatment to determine the dose received by the patient, this precaution would be invalidated by the steady increase in the radiation received. A second point is that this secondary radiation is all in wavelengths so great that it would be absorbed by glass, so that if the treatment were conducted by following the readings of an ordinary glass-enclosed thermocouple, the increase in radiation would not be detected.

It therefore became necessary to devise an instrument for the measurement of radiation flux in all wavelengths, and to recommend that the basis of treatment should always be direct measurement with such an instrument of the actual flux received on the patient's skin throughout the treatment [7]. This recommendation is in contrast to that for X-rays, where the physician relies on calculation of the dosage [8]. It is indeed possible to calculate the infra-red dosage received in any given set of circumstances, but such calculations are too involved to be a feasible method for the ordinary physician.

The instrument devised [9], [10] consists of a pair of disks, carrying thermojunctions on their reverse faces, mounted on opposite sides of a small copper block (figure 3). One disk receives the radiation flux to be measured, while the other is opposed to a water jacket with a blackened surface,

through which water at room temperature is flowing. The construction was aimed at securing a direct-reading instrument responsive to the whole range of infra-red radiation likely to be encountered, accurate to within about 5 per cent., and independent, as far as possible, of the air temperature in which it had to operate. The assessment of the physical factors involved, which were concerned with the transfer of energy by radiation and conduction under conditions removed from thermodynamic equilibrium, proved surprisingly tricky. The final instrument, which shows a linear response to radiation flux, seems to approximate to the best compromise between a number of conflicting physical requirements, and fulfils the conditions imposed reasonably satisfactorily. It also satisfies the medical requirements of robustness, ease of reading, and cheapness of construction. It should therefore now become possible to develop a satisfactory quantitative control of infra-red treatment leading to a better understanding of the effects of this type of therapy. The most important deficiency at present is that so far it has not proved possible to obtain independent measures of the radiation in various spectral ranges, but this is not a serious defect, since, as far as is now known, there is little difference in therapeutic effect between different infra-red wavelengths except for some difference in depth of tissue penetration.

It may be of interest to recall some of the other types of problem dealt with in this general programme. They ranged from the development of methods for the measurement of pressures in small anatomical cavities [11], such as the middle ear; the manufacture and use of devices for measuring subcutaneous [12] and skin-temperature [7], [13], and the construction of a device for the accurate measurement of the volume of a limb; to theoretical analyses of the processes involved in the transmission of light through tissues [14].

It should be pointed out that this account is of a partial nature and is concerned mainly with the work with which the writer has been concerned, but it would be unfair to omit to note some of the more important work which has been carried out by other workers in the field. An excellent summary of work done in Great Britain is provided by the *British Medical Bulletin*, 3, 6, 1945, containing a general introduction by Professor Mayneord, whose work on infra-red radiation has already been mentioned; an article on biophysical factors in drug action by Dr H. Hurst; a survey of the application of electronics to medicine by Dr G. E. Donovan; and a discussion of the physical factors involved in the causation of brain injuries by Dr A. H. S. Holbourn. The wide field of the applications of electronics to medicine, the recent development of the use of artificially radioactive substances in physiological investigations, and the use of increasingly high-voltage X-rays and of neutrons in medical treatment [15], are among the most striking applications of physics to medicine. They have already attracted a considerable number of workers, particularly in the United States, but it has been our own experience, which is borne out, for example, by Dr Holbourn's fruitful application of the classical notions of elasticity and hydrodynamics to the study of brain injuries [16], [17], [18], that there remains a very large field in which less spectacular physics may aid medicine.

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Aerial photography

C. H. WADDINGTON

Cartography is a science essential in both war and peace, though historically the main impulse to the making of maps has been military: the Ordnance Survey was originally a branch of the Royal Artillery, and Napoleon's campaigns led to the first detailed maps of France. The war of 1939–45 stimulated the effective development of cartography by means of aerial photographs. Professor Waddington discusses the possibilities and limitations of the method, and shows the importance of aerial photography for peaceful purposes.

It is well known that during the war aerial photography was one of the most important means of finding out what was going on in enemy countries. In the early days, when Britain was expecting an invasion, it was vital to know if, and where, the Germans were collecting barges and landing craft: it was a task for the Royal Air Force, with its cameras, to keep a continual watch on the Continental ports. Later it had to provide the information by which we could judge the success of our bombing offensive, and the effectiveness of various types of attack. Through the newspapers we became familiar with aerial photographs of acres of devastation in German cities. But these were only the most spectacular, and the most fully publicized, of the achievements of aerial photography. In a more general sense we can say that this technique has become the modern equivalent of cartographic surveying. Generals have always demanded the fullest possible information about the country in which they are to fight, and this demand has been one of the crucial arguments which have persuaded countries to undertake the laborious work of preparing accurate maps. The connection between map-making and military affairs is reflected in the name of the official agency for mapping Great Britain—the Ordnance Survey—which was originally a branch of the Artillery. Similarly, the official maps of France are those originally produced by Napoleon for military purposes.

A century or more ago the military demand for information about potential battlefields was generally met by a survey, conducted on the ground, which recorded only the physical shape of the solid earth and the main features such as roads and towns. Nowadays aerial photography provides not only an accurate map of the same features but also a very detailed account of the nature of the land surface. This may often be of fundamental military importance: a commander will want to know not merely that there is an open area between two roads, represented by a blank space on the map, but much else besides; is it hard ground suitable for tanks, or swampy, or covered in bushes? All this can easily be read from the aerial photographs, and expert examination can extract an extraordinary wealth of information from them. Much of this is, of course, of even more importance for peacetime pursuits than for warlike ones. Normal cartographic maps, prepared originally for soldiers, are recognized as essential tools for all kinds of civil enterprises, not only for legal battles about boundaries, but for every major undertaking of engineering or construction. Aerial photographs, because of the more complete information they may contain, will become the new form of map essential for undertakings of agricultural development, forestry, control of erosion, and so on. The military organization built up for interpreting aerial photographs during the late war is likely to be gradually absorbed, in some form or other, into the service of civilian affairs, just as the Ordnance Survey was in an earlier period.

This does not necessarily mean that surveying on the ground has gone out of date. It will probably remain for some time a better method of obtaining extreme accuracy than surveying from the air. If we are concerned only to produce a physiographic map of the normal kind, the advantages of the air are not in greater accuracy but in rapidity. It is, for instance, obviously very easy to use aerial photography to make frequent revisions of an already existing map, so as to keep it up to date. There are even greater advantages in undeveloped countries where travel is difficult. Aerial photography can be used to fill up the spaces in a grid of points whose position has been fixed by triangulation on the ground, but it will probably soon be possible to dispense with all ground control over very wide areas. Experiments

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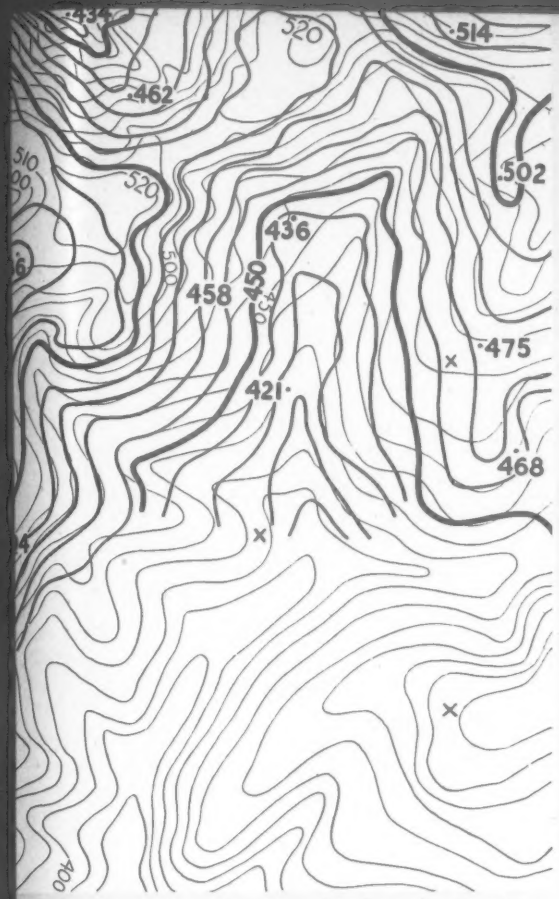


URE 1 – *Comparison of contours based on the use of r fixes (heavy lines) to locate the photographing aircraft in e, with the contours recorded by accurate ground survey. ntours at 100 ft. intervals.) The material was worked out n one of the first experimental flights, the nearest ground ion of the radar system being 85 miles away.*

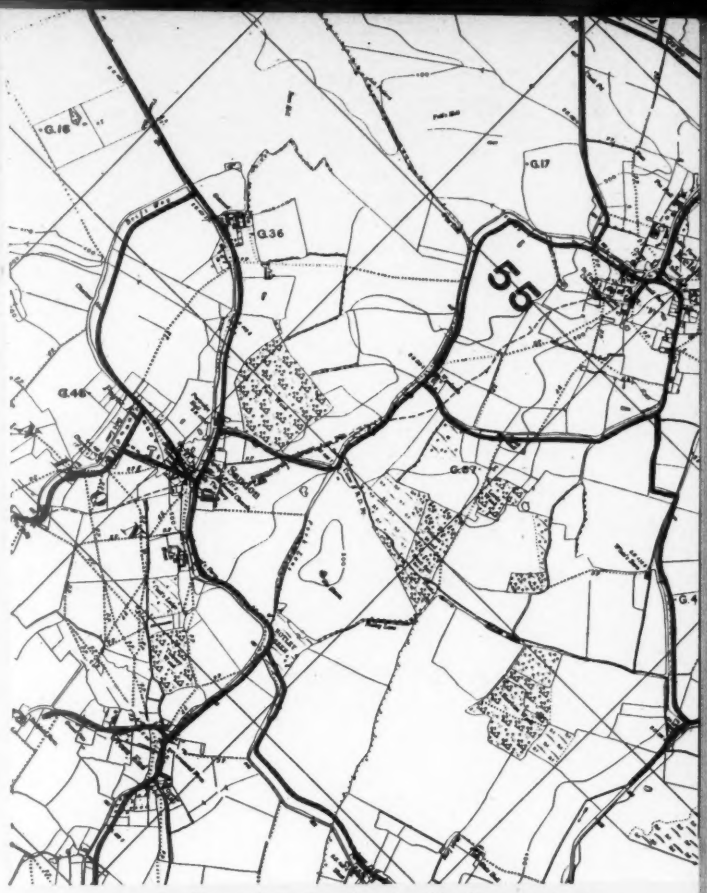


FIGURE 2 – *Comparison of roads mapped in the same experimental radar-controlled flight with those recorded by ground survey. (The roads mapped by radar are printed in black.)*

FIGURE 3 (*below*) – *Venice, showing the Piazza S. Marco.*

FIGURE 4*a* – *Boulogne harbour at low tide, with the dredged channels showing up clearly.*

FIGURE 4*b* – *Boulogne harbour during the maximum spring tides, showing how a whirlpool is formed in the mouth of the harbour by silt-laden water.*

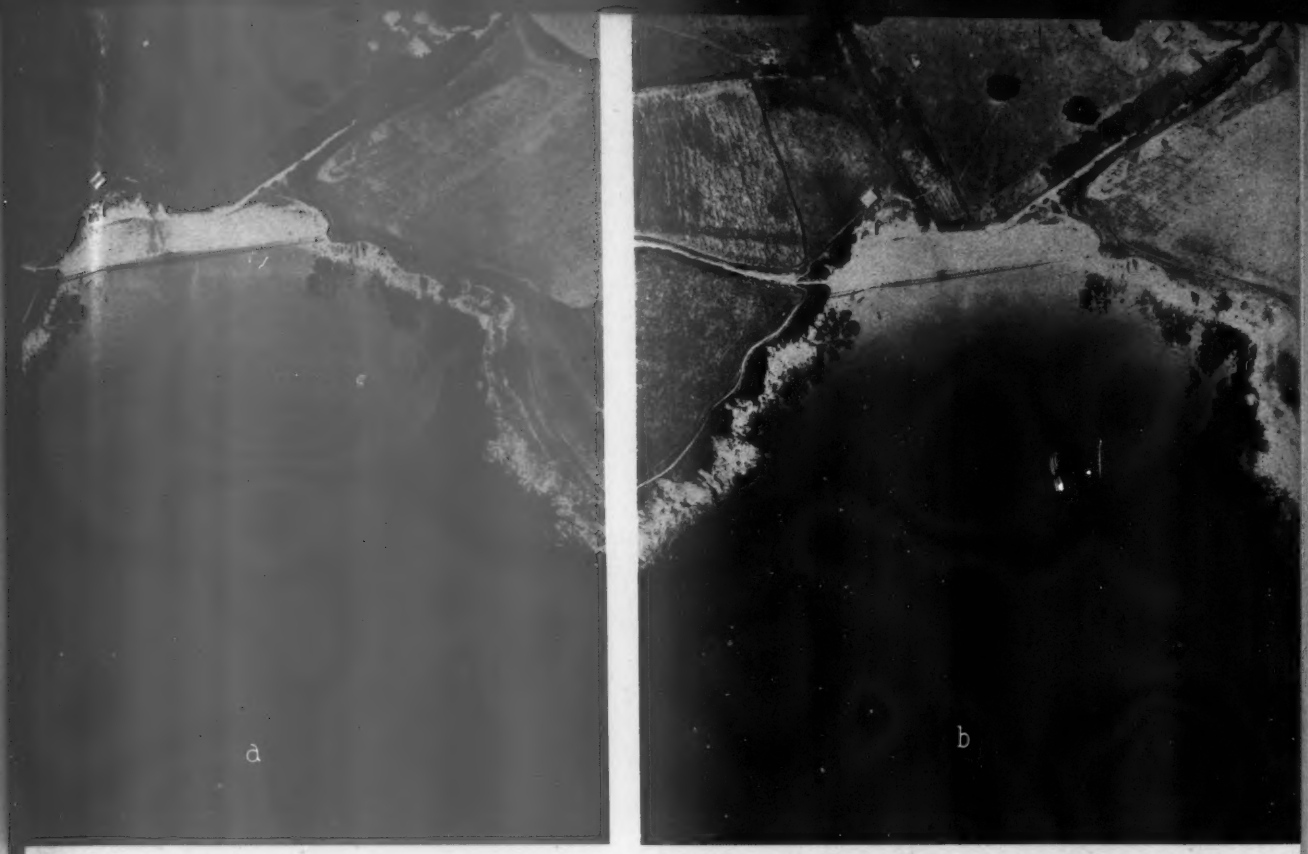
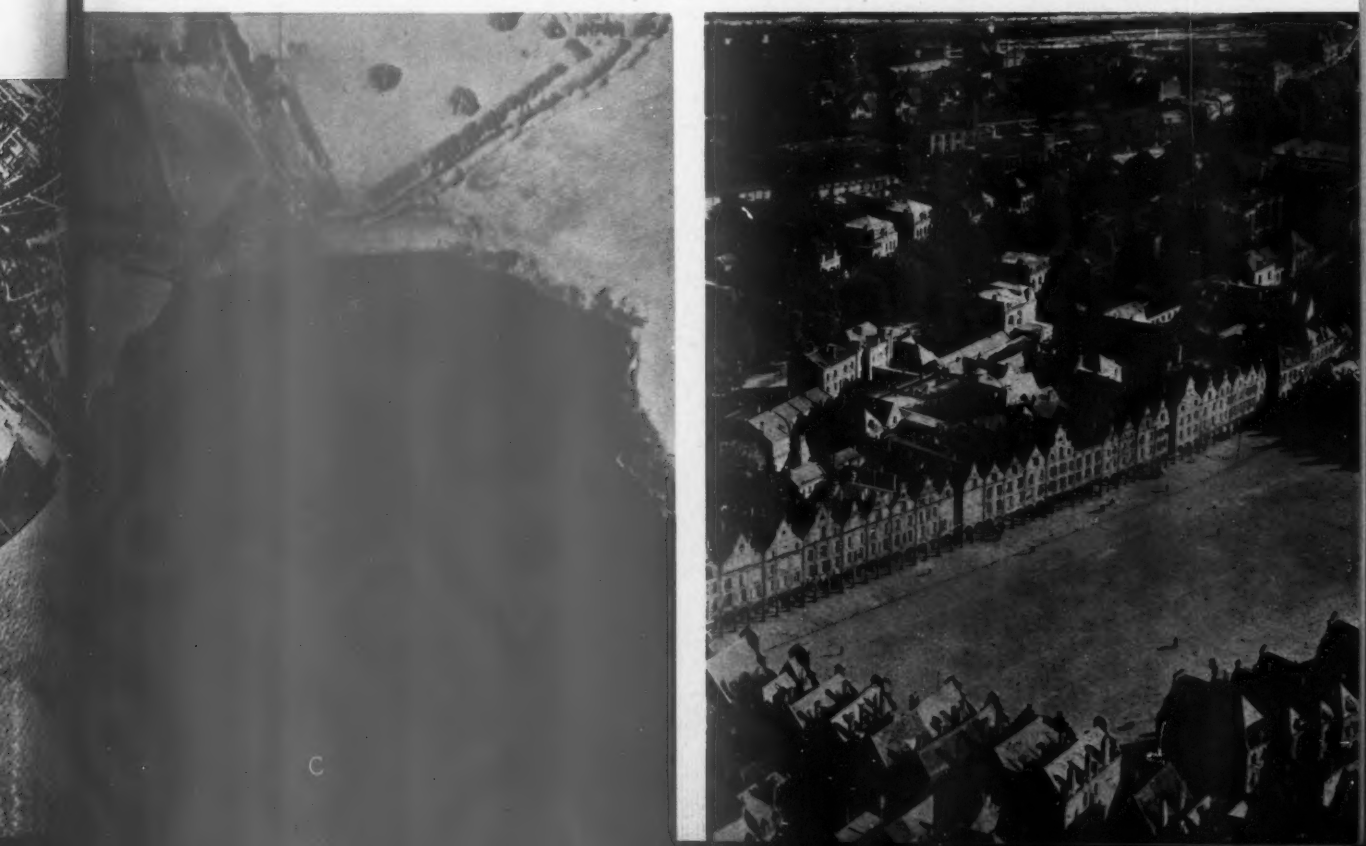


FIGURE 5 – *Three photographs, taken through (a) green, (b) red, and (c) infra-red filters, of a sandy cove in Cornwall. Notice the steeper gradation of tone in the sea on the red photograph in comparison with the green one. Notice also the position of the water-line, which is sharply revealed by the infra-red.*

FIGURE 6 (*below, right*) – *An oblique photograph, showing the eighteenth-century Dutch gabled houses in the Grande Place at Arras.*



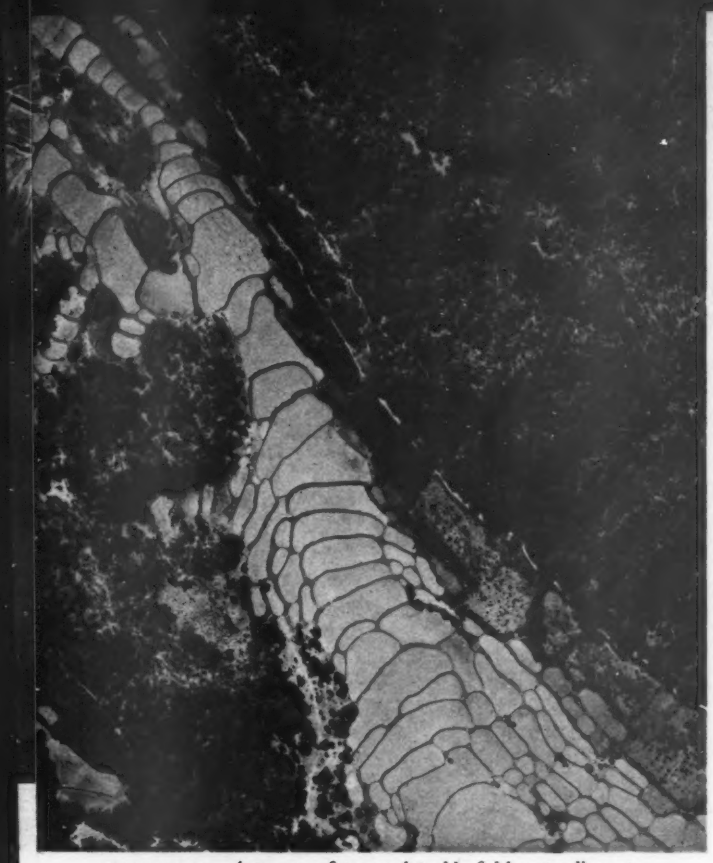
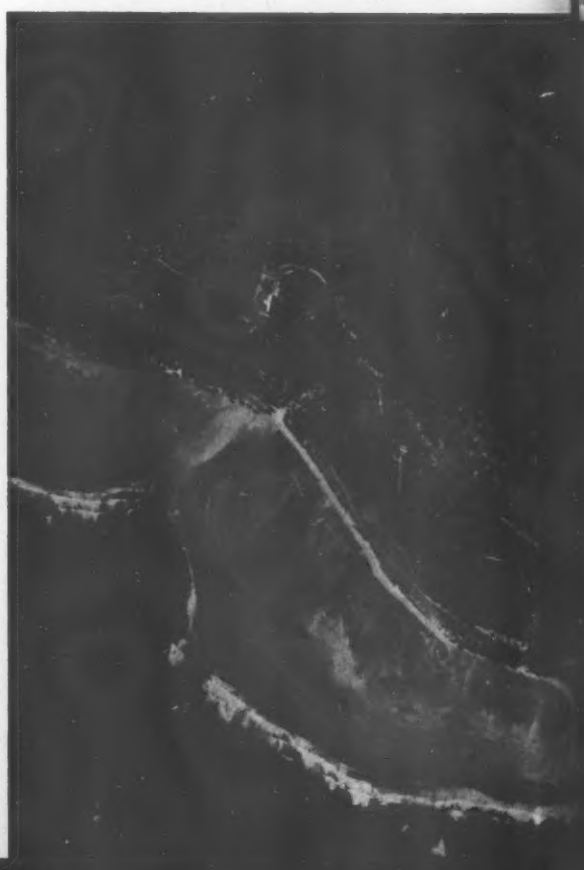


FIGURE 7 – *A tongue of terraced paddy fields extending up a small valley.*

FIGURE 8 – *A village with scrub on one side, and, on t other, fields with ground-nuts and similar crops.*

FIGURE 9 – *Most of the larger fields shown here contain bush crops such as tobacco, but there are also some small rice fields in the low-lying parts.*

FIGURE 10 – *A coco-nut plantation, with deciduous fo behind it. The beach is a coral reef.*



URE 11 – *In this difficult country, two types of jungle be easily distinguished.*

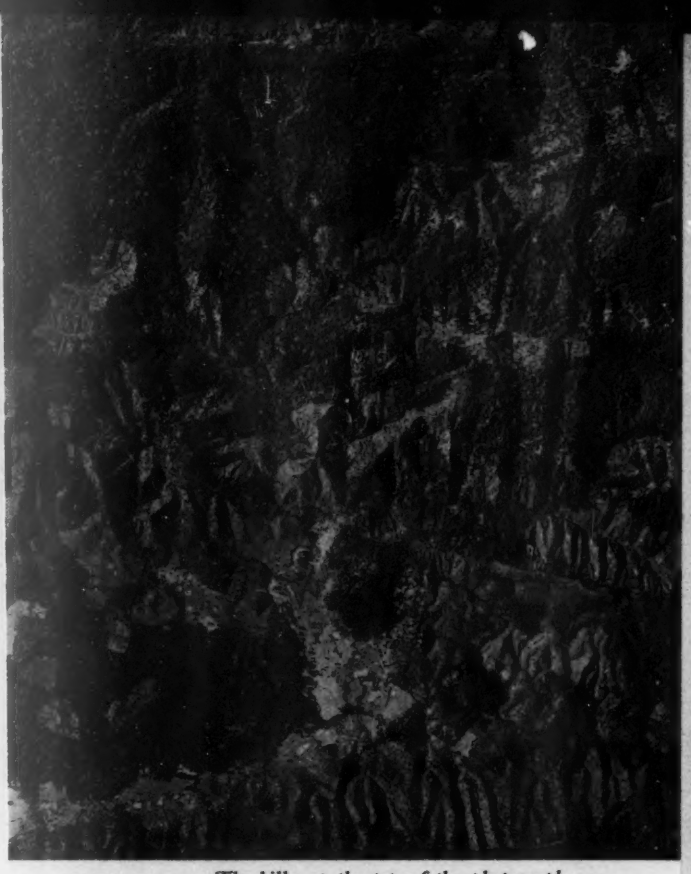


FIGURE 12 – *The hills at the top of the photograph are covered with relatively untouched jungle, but over most of the area the hillsides have been felled and burnt, the land used for a few crops, and then allowed to revert again to forest.*

FIGURE 14 – *Houses set amid coco-nut groves, photographed with a moving-film camera* (*page 84*).

URE 13 – *A cultivated plain, beginning to suffer badly erosion along the valleys.*

FIGURE 15 – *Den Helder, a Dutch town which is nearly enclosed within its ancient fortifications.*

are now proceeding on the use for survey purposes of some of the radar devices which were developed to aid the navigation of a bomber to its target at night. By means of these instruments one can determine the position of the aircraft, relative to the two or more ground stations transmitting the signals, at the instant of photography. Very accurate maps can then be made up to distances—at present—of a few hundred miles. An example, from one of the first experimental flights, is illustrated in figures 1 and 2. This technique is very rapidly advancing, and it is likely that it will soon be able to play an important role in surveying many comparatively undeveloped regions of the world.

One rather specialized branch of surveying work in which the cheapness and speed of air photography show to unexpected advantage is the investigation of the under-water topography near the shore. By choosing favourable conditions of wind, sun altitude, and other factors, it is possible to take aerial photographs which register details of the bed of the sea down to twenty or thirty feet, which is deep enough for most practical purposes of coastal navigation. Figure 4 shows how one can get an overall picture both of the success of harbour dredging and of the currents which bring in the silt. These photographs were taken in routine reconnaissance. Much more exact information can be obtained by special techniques. Perhaps the most generally useful of the latter is simultaneous photography through red and green filters. Through a green filter the bottom can be seen to a greater depth than through a red one; in a green-filter photograph the graduation in tone from the shore to the black of the deep sea will therefore be more gradual than in a red photograph (figure 5). By expert comparison of the two photographs depths can be determined with considerable accuracy, the maximum range depending on the nature of the bottom, the muddiness of the water, and other factors. This type of interpretation can be reliably done only by experts, but their results compare very favourably with those obtained directly by the laborious process of taking soundings (figure 16).

It is when the aerial photograph is considered as a supplement to a map, giving information which is normally not plotted by cartographers, that its greatest advantages appear. For town planning, for instance, a set of air photographs will not only give an accurate picture of all the recent additions to the town and make it possible to work out the heights of buildings as well as their plan position, but will show the character of the town in a vivid and realistic way which is quite impossible on a map. The town planner can get his photographs at the scale which is most appropriate for his particular interests (figures 3, 6, and 15). He may want to study a whole region, and the relation between town, agricultural land, forests, parks, hills, and so on; or he may be interested in more detailed matters. In any case the air photograph will present the material in a way which, unlike the normal map, does not omit the aesthetic qualities on which good town planning so largely depends.

Another most important use of aerial photography in peacetime will be for the preparation of land-utilization maps. One can, of course, very easily distinguish the main categories of land—arable, grassland, woods, parks, and so on; and land-utilization maps can be made which are not out of date before the survey has been completed, an achievement which is scarcely possible when such maps are made from ground studies unless a prohibitively large staff is employed. From aerial photographs, moreover, one could go into considerably greater detail than is worth attempting in ground maps which can be revised only at long intervals. Many of the most important crops can be distinguished in photographs on quite a small scale. More research is still needed on this type of interpretation; many of the appearances presented by crops at different stages of their growth are somewhat unexpected and deceptive to the layman, but it is clear that we can already get much more up-to-date information about the purposes for which land is used than has been available before.

This may be of particular importance in regions which are comparatively undeveloped, where agricultural statistics are usually even more incomplete than in the longer-settled countries. Figures 7–11 show some typical examples of various agricultural crops growing in Burma: clearly from such photographs one could make fairly exact estimates of the acreage used for different purposes. Moreover, the administrator can keep a continual check on the fleeting cultivations which some semi-nomadic peoples set up in the jungles (figure 12), and can discover when the burning of the cover of trees is going too far, or erosion is becoming dangerous (figure 13). A valuable indication of forest resources can also be obtained: the main ecological types of forest can be mapped, and, if necessary, the supplies of

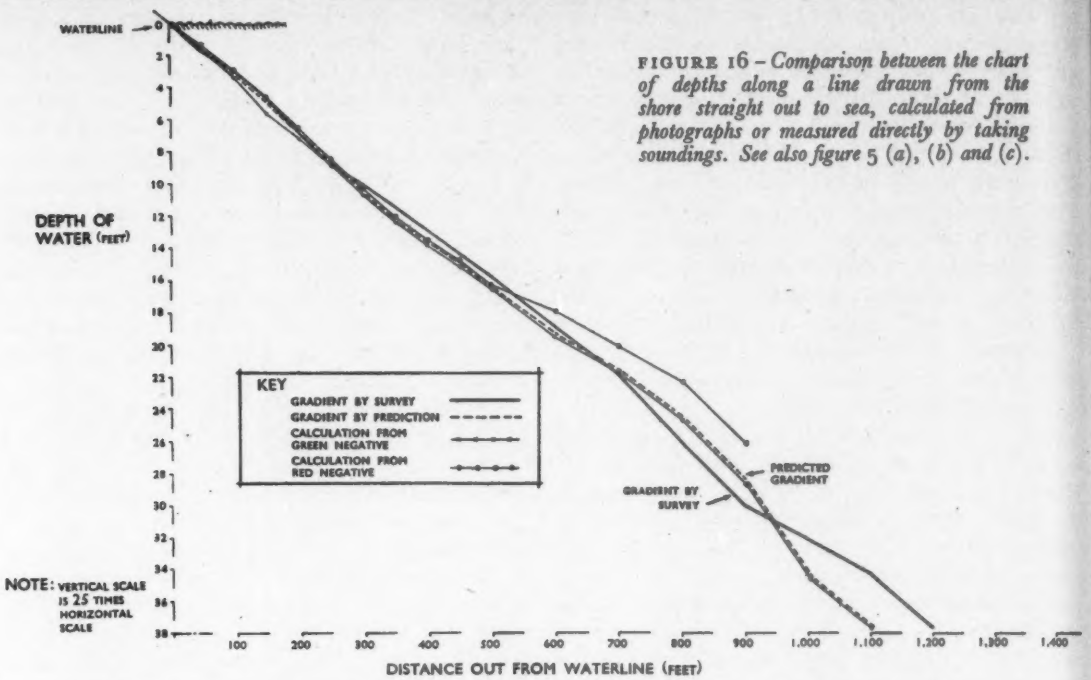


FIGURE 16 – *Comparison between the chart of depths along a line drawn from the shore straight out to sea, calculated from photographs or measured directly by taking soundings. See also figure* 5 (*a*), (*b*) *and* (*c*).

particular trees such as teak or wild rubber estimated.

There is another wartime technical development which has a certain contribution to make to vegetation surveys and similar projects. This is the moving-film camera, in which the film can be moved during the exposure so as to compensate for the movement of the image caused by the speed at which the aircraft is travelling. This compensation is of importance only when high-speed aircraft are travelling rather low down. With this system it is possible to take sharply focused vertical photos at such large scales that they eliminate the need for any checking on the ground of the accuracy with which the usual small-scale photos have been interpreted (figure 14). This has great advantages in inaccessible country. If, for instance, one wishes to be certain of the different species of trees in a region like that shown in figure 11, it would be tedious to have to send an expedition to verify the photo-interpretation; but the job could be done quite quickly with a low-level, vertical photograph of this kind.

There has been space to mention only a few of the uses of aerial photography for peaceful purposes. Those which have been chosen for illustration are those which can be most generally applied to almost any region of the earth. Many other applications have been made more locally. For instance, in some countries aerial photos clearly show the boundaries of different soil areas. In some parts of the world, particularly uncultivated countries, a great deal of geological information can be deduced from them, and rough geological surveys can be made with a minimum of ground work. There have also been many quite local problems where air survey has been extremely valuable—for siting reservoirs, power cables, roads, and so on. Much use has also been made of the method in archaeological work for discovering the position and extent of ancient fortifications, circles, burial mounds, and other artifacts. It would take too long to try to enumerate all these possibilities, and in any case the list would certainly be incomplete. Enough has been said to show that in aerial photography we have another technique which can supplement ground mapping with new applications of as wide, though somewhat different, a scope.

The spectroscopy of flames

R. F. BARROW

Flame spectra are very complex, and it is only since the development of quantum theory that substantial progress towards their elucidation has become possible. Difficulties may arise owing to the necessity for distinguishing between chemiluminescent and thermal phenomena. Dr Barrow here reviews recent work, and makes the interesting point that chemiluminescence may in the future have an important part to play in lighting systems.

Recognition of spectroscopy as a valuable tool for investigating the nature of flames dates from the work of Bunsen and Kirchhoff, published in 1859. Their fundamental observation that elements are characterized by spectral lines of definite wave-length stimulated the empirical study of spectra, of which the most striking results were the discovery of new elements and Crookes's identification of Lockyer's line in the solar spectrum with that derived from terrestrial helium. Such line spectra were attributed to emission of light from atoms, and band spectra to emission from particles of greater complexity, but in the latter case experimental evidence was by itself insufficient to identify the emitters unambiguously. The interpretation of band spectra had to await quantum theory, the application of which to the analysis of the spectra of simple molecules, particularly those consisting of only two atoms, was finally worked out in the period 1925–35.

The study of flame spectra followed this general development, so that the earlier work was directed mainly towards identification of atomic and molecular species. The results of this work were somewhat surprising. It was manifest that flames consist of mixtures of reacting gases, sometimes with dispersed solid smokes, often at fairly high temperatures. That they contain unusual chemical species was evinced by their electrical conductivity. That certain atomic spectra, for example those of the alkali and alkaline earth metals, were found to be of frequent occurrence was not unexpected. The vapours of these elements were known to be largely monatomic, and the actual atomic concentrations required for light emission were found to be exceedingly small. What was at first remarkable was the nature of the molecular species identified—unstable radicals, unknown to the chemist under ordinary conditions, such as C_2, CH, and OH. Analysis of the fine structure of their spectra, however, left no doubt of the correctness of their identification, while at about the same time their existence under such conditions became more readily credible as workers in the field of chemical kinetics found it necessary to postulate their participation in photochemical and thermal chain reactions.

Apart from the line and band spectra, which may be characterized, if not always in the latter case immediately identified, by wave-length measurements, many flames emit continuous spectra the elucidation of which necessarily requires more subtle experimental investigation. Such continua may arise either from incandescent solid particles present in the flame or from a variety of atomic and molecular processes, some of which will be considered later.

The first problem in the study of flame spectra must always be the identification of the emitting species. This often presents experimental difficulties which increase with increasing weight and complexity of the emitter. Even in diatomic spectra the only certain methods depend either on rotational analysis, which gives information about the molecular quantum numbers and the interatomic distances, or on comparison with absorption spectra obtained under clearly defined chemical conditions. Both methods are subject to limitations. Rotational analysis requires the use of large spectrographs of high resolving power, but the amount of light available in flames is frequently very small, so that the necessary length of exposure may be almost impracticable. In addition, in presence of the continuous radiation which so frequently accompanies the discrete spectra, it may be difficult to secure adequate contrast of the structure lines on the photographic plate. The method of comparison with absorption spectra is of course confined to those systems which involve the ground electronic state of the radical concerned (which is, however, very often in this state), and to those species which are of not

too great chemical instability. In spite of these difficulties it has been possible to identify with certainty a high proportion of the diatomic radicals whose spectra occur in flames, and indeed, owing to their particular excitation characteristics, the reverse process has sometimes been employed, i.e. flames are sometimes useful sources for the spectroscopic examination of molecules which do not appear to emit light readily under other experimental conditions.

The difficulties of identification are greatly multiplied in the flame spectra of radicals or molecules containing more than two atoms. In place of the definite answers which spectroscopy can give about atomic and diatomic emitters, the identification of the substances responsible for electronic band systems of polyatomic molecules is much less certain. It then generally becomes necessary to take into account more ambiguous evidence, relating for example to the probable concentrations of transitory intermediates. At least three such systems—the carbon monoxide and hydrocarbon flame bands and the ammonia α-band—are of some importance in connection with theories of combustion, and it is unfortunate that in no case is the identity of the emitter immediately demonstrable.

The spectrum of the flame of carbon monoxide burning in air or oxygen consists of a faint system of bands superposed on a strong, continuous background which extends through the visible and near ultra-violet regions of the spectrum, and is strongest in the range 3,500–4,500 A. It has been concluded that the emitter is probably carbon dioxide [1], [2].

The ethylene, or hydrocarbon, flame bands, which lie in the range 2,500–4,500 A, are associated with the flames of burning hydrocarbons: they occur, for instance, in the inner cone of the ordinary Bunsen flame, and were first described in detail by Vaidya [3]. Gaydon has studied this spectrum recently [4], and has shown that its production runs parallel with the formation of peroxides in the flame. Like Vaidya, he assigns the bands provisionally to HCO, but remarks that alternative emitters cannot be entirely ruled out.

The ammonia α-band, a complex 'many-lined' spectrum, appears in the oxy-ammonia flame, and is responsible for its yellow-green colour. It has been ascribed by Rimmer [5] to NH_2.

The study of continuous spectra has been somewhat neglected by spectroscopists, perhaps naturally enough in view of the abundance of discrete spectra to be photographed and analysed, but as a result of this preoccupation there is surprisingly little quantitative information available about continua. And it is quantitative information which is now in question, for the only means of characterizing such spectra precisely is by way of data giving the intensity of the continuum as a function of wave-length, i.e. of energy. Before discussing any individual examples it will be as well to consider briefly some of the possible mechanisms by which light can be produced in flames.

The ultimate aim of quantitative spectroscopy is to relate the intensity to the probability of the particular event leading to light emission at a given wave-length and the number or numbers of particles involved in that act. The general formulation of this problem was given by Einstein. Considering the transition from an excited state 1 to the ground state 0, for the total energy emitted per unit time per unit volume, $\bar{S}_{1,0}$ we have:

$$\bar{S}_{1,0} = N_1 . h\nu_{1,0} . A_{1,0}$$

where $\nu_{1,0}$ is the frequency of the light emitted,
N_1 is the number of atoms or molecules per unit volume in state 1, and
$A_{1,0}$ is the 'transition probability,' which is often given simply by the reciprocal of the life-time in the excited state, τ_1.

The processes responsible for light production can be divided broadly into two classes: (*a*) thermal excitation, and (*b*) chemiluminescence, and we will take these in turn.

It appears probable that, in many flames at least, the mechanism of light emission by radicals or solid particles is due merely to collision with charged or uncharged molecules or with atoms possessing high thermal energies. On a simple view, if we assume that temperature equilibrium is established for the different modes of energy intake, we can apply the Boltzmann distribution law to get the number of particles in the upper state N_1, and we find that there should be an exponential dependence of $\bar{S}_\lambda$ (the value of $\bar{S}$ at some wave-length λ) upon absolute temperature T of the form $\bar{S}_\lambda = C.e^{-h\nu/kT}$, where C is a constant. The interest of this expression is that, although it is experimentally very difficult to measure absolute values of the intensity—indeed reliable measurements have been made for only a few atoms and for one or two diatomic molecules such as OH and CN—we can get relative intensity values without too much difficulty, and such data provide the basis of the spectroscopic methods of temperature determination.

For this, the distribution of molecules among either vibrational, or, better, rotational, states may be used. Alternatively, and far more conveniently, the line-reversal method can be employed. The principle of this is as follows. The reversal of spectral lines, e.g. the sodium *D* lines excited by adding small amounts of a sodium compound to the flame, is examined in a visual spectrograph against a background of variable brightness such as may be obtained from a tungsten strip filament lamp. When the lines just merge into the continuous background the flame and the continuous source are at the same black-body temperature, which may be measured on the latter with an optical pyrometer. It should be mentioned that there has been some criticism of this method, directed against its basic assumption that the atomic radiation is purely thermal, but that it does apply in a fair number of cases is shown by data quoted, for example, by Jost [6].

The variation of the intensity of emission with wave-length at a constant temperature is, of course, different for different cases. A continuum arising from incandescent particles would obey Planck's distribution law for black-body radiation—or rather the law as modified for a grey body, taking into account the departure from unity of the emissivity of the particles. Unfortunately, emissivity data, except for a few technically important substances, are rather meagre. In the case of discrete or continuous light emission arising from a transition between two electronic states, the wave-length distribution of intensity will depend upon the relative disposition of the potential energy surfaces in upper and lower states (Franck-Condon principle), on the statistical weights of these and of the sub-states, and on the Boltzmann distribution function for the upper state. Since the amount of energy available for thermal excitation in ordinary flames is comparatively small, the discrete electronic systems observed almost invariably involve the ground state as the lower state of the transition. As has already been remarked, it is not yet possible to give any coherent picture of the continuous spectra of flames. One important type results from the recombination of an electron with a positive ion to form a neutral atom. A continuum whose origin seems to be still somewhat in doubt, but which is remarkable for its intensity, is that which appears more or less symmetrically disposed with respect to the resonance lines of sodium and potassium (and presumably the other alkali metals) when the metal is burned in oxygen or is introduced into a hydrogen-air flame or into the hollow cathode of a Schüler tube. Preliminary observations on the sodium-hydrogen-air flame suggest that the intensity is proportional to the concentration of alkali metal, and that it may have a temperature coefficient of the order expected for thermal excitation.

When a mixture of carbon disulphide and nitric oxide is exploded a brilliant flame is produced, which from the quantity of light emitted (apparently largely from the S_2 band spectrum) would correspond to black-body radiation at a temperature of about 5,000° K [7]. Again, under certain conditions, it is possible to get organic substances such as ether, acetaldehyde, and hexane to react with oxygen at rather low temperatures (200–400° C) with simultaneous emission of light. The latter flames have been photographed by Emeléus, and the spectra, which are all identical, have been shown by Pearse to be due to formaldehyde. It is clear that there is no direct relation between the temperatures of such flames and their luminosity, and it must be concluded that the light emission is due to some chemiluminescence process, whereby sulphur in the former case and formaldehyde in the latter are produced in excited electronic states. Let us briefly consider what might be expected of such a process.

The fundamental distinction between chemiluminescence and thermal excitation depends on the predicted numbers of excited species, N_1.† If, for example, a radical C is formed in an upper state by a chemiluminescence reaction

$$A + B \rightarrow C^*,$$

C^* thence falling back to the ground state with emission of radiation,

$$C^* \rightarrow C + h\nu,$$

then provided that deactivation processes of the type

$$C^* + M \rightarrow C + M$$

are unimportant, almost every C^* formed will radiate energy, instead of only the Boltzmann fraction of the stoichiometric concentration of species C, $\varepsilon^{-h\nu/kT}$, for pure thermal excitation. Furthermore, in a chemiluminescence process, the effect of temperature on intensity will be determined by the activation energy of the reaction $A + B \rightarrow C$ (or by that of the rate-determining

†A clear experimental distinction between chemiluminescence and temperature radiation is by way of Kirchhoff's law, which states that at a given temperature the ratio of emissive power to absorptivity is constant and equal to the emissive power of a perfect radiator. This law is based on the assumption of thermal equilibrium and is therefore not obeyed by chemiluminescent systems.

step in the cycle of events which leads to the production of *A* and *B*) rather than by the quantity $h\nu$.

The most thoroughly investigated reactions of this type are those between alkali metals and the halogens or halogen-containing compounds at low pressures in the dilute flames of Polanyi. In the case of sodium and chlorine an efficiency of about unity can be obtained for the light emission of the *D* lines. The most probable mechanism is:

$$Na + Cl_2 = NaCl + Cl$$
$$Na_2 + Cl = NaCl^* + Na$$
$$NaCl^* + Na = NaCl + Na + h\nu$$

where NaCl* refers to a sodium chloride molecule of high vibrational energy content.

The best-known example of a chemiluminescence continuum is again provided by the alkali metals and the halogens, for which recombination spectra due to processes of the type

$$Na + Cl = Na.Cl^* \quad \text{(homopolar upper state)}$$
$$Na.Cl^* = Na^+.Cl^- \text{ (ionic ground state)} + h\nu$$

have been observed.

So far we have considered the bearing of chemiluminescence alone on electronic energy changes, but it appears also that thermal equilibrium may not always be attained for the other forms of energy intake. Thus the rotational temperatures of C_2 and CH in one and the same discharge through acetylene were found by Lochte-Holtgreven to be 4,700° and 2,000° K respectively. That this is not an unfair example is shown by the vibrational intensity data of Kondratjew and Ziskin [8] for a hydrogen-oxygen flame. They found that the (2, 1) band of the OH system was stronger by a factor of the order of 50 than it should have been had the vibrational energy distribution been thermal. Similar evidence that there is sometimes a delay in reaching equipartition for vibrational energy has been adduced from studies of vibration-rotation bands in the infra-red.

It is of considerable importance to establish whether or not the vibrational or the electronic energy is chemiluminescent or thermal in origin. If chemiluminescence processes obtain, then clearly the scheme postulated for the overall reaction must make provision for the formation of such species in excited levels. It would take us too long to consider any one case in detail—even the mechanism put forward for the burning of hydrogen in oxygen to form water is a formidable affair—but it is worth noting that in this reaction the spectroscopic evidence that the OH emission must be chemiluminescent is of considerable value in assessing the relative importance of some of the different reaction steps suggested.

This question has also a very direct bearing on practical problems of light production. It has already been mentioned that the emission from the carbon disulphide-nitric oxide flame corresponds in efficiency to a black-body radiator at about 5,000° K. It has been calculated to be about 83 lumens/watt. 5,000° K is, of course, an impracticable temperature for a terrestrial flame. If we take 2,000° K as a reasonable figure, we get an efficiency of light production of only 1·7 lumens/watt, so that the chemiluminescent source is, on an energy basis, some fifty times as efficient as an ideal black-body source at 2,000° K. So far, no one has succeeded in developing any such chemiluminescent source on any considerable scale.

Finally it should be noted that spectroscopic measurements in absorption provide us with the possibility of determining the concentrations of radicals. This may be done directly to determine stationary concentrations in flames, but what is probably of greater interest is the possibility of observing changes of concentrations with time in discharges, and thus exploring the kinetics of their production, decay, and transfer of energy. Such studies of radical kinetics are difficult, and the results are not necessarily immediately applicable to the radical reactions occurring in flames, but they should nevertheless form an increasingly valuable supplement to data derived from the more orthodox methods of chemical kinetics.

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Molecular sedimentation in the ultracentrifuge

THE SVEDBERG

The sedimentation of particles of molecular dimensions can be experimentally observed if the equivalent of an intense gravitational field is produced by centrifugal force. The necessary conditions can be created in an apparatus known as the ultracentrifuge. The latter has proved particularly useful in the study of the homogeneity of proteins and the determination of their molecular weights. The technique has also been successfully used in the study of other natural and synthetic polymers such as cellulose, rubber, and polyethylenes.

The sedimentation or settling of small particles under the influence of gravity is an everyday phenomenon which plays, and has played, a great part in geophysics. Clay deposits, old and recent, are formed through the fractionating effect of the sedimentation of particles carried by the water of streams and rivers to the lakes and the ocean. With decreasing size of particle the sedimentation becomes slower and slower, until the inevitable thermal convection currents stop it altogether. The greenish colour of many glacier lakes is due to minute particles floating in the water.

If the size of the particles is further diminished, to molecular dimensions, another phenomenon comes into play, namely the diffusion or irregular thermal motion of the individual particles or molecules. The atmosphere surrounding the earth is kept from flying away into planetary space by sedimentation, and is prevented from settling down as a dense layer on the surface of the earth by diffusion. The state resulting from this combination of sedimentation and diffusion is called sedimentation equilibrium. If we want to use the sedimentation of molecules for analytical purposes in the laboratory, the force of gravity has to be increased hundreds of thousands of times. This can be accomplished by means of swift rotation in a specially designed centrifugal apparatus, the so-called ultracentrifuge.

The first measurements of molecular sedimentation were performed at Upsala in an oil-turbine ultracentrifuge constructed for that purpose. Since then other types of ultracentrifuge have been devised, using compressed air or electric current of high frequency as the driving agent. Whatever the driving force, the solution to be studied has to be enclosed in a small cell of sectorial shape with windows for optical measurements. This cell has to be mounted in a rotor spinning at constant temperature in hydrogen at low pressure, or in a perfect vacuum (figure 1).

Particles or molecules in a centrifuge travel towards the periphery along radii, hence the sectorial shape of the cell. Constant temperature has to be maintained in order to avoid disturbing convection currents. In the case of the oil-turbine ultracentrifuge the rotor is provided with two small turbines, one at each end of the shaft, acted upon by oil under pressure. To avoid vibration the rotor and its cell are carefully balanced, and the bearings are provided with a special damping device. A solid steel casing protects the observer and instruments in case of failure of the rotor material (figure 5).

The methods of observation used so far are based on either the absorption or the refraction of a beam of light passed through the rotating cell. The former is more direct and easier to understand, the latter more precise (figures 2 and 3).

In the former case each molecular species shows up as a step on the curve, in the latter as a peak. By such methods the molecular composition of a solution can be studied. If only a few molecular species are present, each of them of definite mass and shape, the analysis is comparatively easy. This is the case with many of the native proteins. Other substances of high molecular weight, such as the polysaccharides, consist mostly of molecules of continuously varying size. In the sedimentation diagram this shows up as a marked broadening of the peak (figure 4).

There is always a certain degree of broadening due to the diffusion or thermal motion of the molecules, but it is much slower in the case of large molecules such as those of cellulose. For comparison with the sedimentation peaks, a pure diffusion peak resulting from the blurring of a

boundary between a solution of cellulose and pure solvent is shown in figure 6.

The time required for the broadening was here fifty hours, while in the case of sedimentation broadening due to the unequal size of the molecules the time was only fifty minutes.

The unequal size of the molecules—the so-called polydispersity—shows up in the diffusion curve in a peculiar way. For a solution containing only one molecular species the broadening of the curve follows the simple statistical laws. In the case of a mixture, however, there is a marked deviation (see figure 6). As a comparison, figure 7 gives the diffusion diagram for a monodisperse substance, serum albumin, and figure 8 the sedimentation diagram for the same molecules. Here the broadening of the sedimentation peak is entirely due to diffusion, and the diffusion follows the simple statistical laws. The molecular weight can be calculated from sedimentation and diffusion according to the formula:

$$M = RTs/\{D(1 - V\rho)\}$$

where M = molecular (or particle) weight,
R = gas constant,
T = absolute temperature,
s = sedimentation constant,
D = diffusion constant,
V = partial specific volume of solute,
ρ = density of solution.

As already mentioned, the combined result of sedimentation and diffusion finally leads to a steady state, the so-called sedimentation equilibrium. The number of molecules per unit volume decreases exponentially in the direction of diminishing force. Thus the density of the atmosphere around the earth falls to half its ground-level value at an altitude of about 6,000 metres, while for a serum albumin solution exposed to a centrifugal field 10,000 times the force of gravity the corresponding distance is only 1 mm.

Owing to the fact that sedimentation equilibrium is dependent upon both sedimentation and diffusion, the molecular weights can be found directly from such determinations by means of the formula:

$$M = \frac{2RT \cdot log(c_2/c_1)}{(1 - V\rho)\omega^2(x_2^2 - x_1^2)}$$

where c_1 and c_2 are the concentrations at the distances x_1 and x_2 and ω is the angular velocity.

The measurement of molecular sedimentation by means of the ultracentrifuge has proved a very useful analytical tool in many branches of science, medicine, and industry.

The blood of all vertebrates and many invertebrates contains a variety of respiratory pigments, either enclosed in corpuscles or simply dissolved in the blood-fluid. The bluish haemocyanins of the snails and crustaceans have molecular weights of the order of millions. Many of these types of molecule undergo dissociation reactions when the environment is changed, resulting in a splitting of the molecule. The reactions are often characteristic of the genus and species.

Thus the haemocyanin in the blood of the snails *Helix* is stable only within a certain *p*H range. Outside this region the molecule is dissociated into well-defined cleavage products with molecular weights one-half and one-eighth that of the original molecule. The parts have the same length as the parent molecule. The haemocyanin of *Helix pomatia* can also be split by the addition of salt. Curiously enough, only three-quarters of the molecules present are sensitive to salt; the rest remain undissociated. Evidently there are two chemically different kinds of haemocyanin molecules present in the blood of *H. pomatia*: one is split both by *p*H change and addition of salt, the other by *p*H change only.

There is a second type of snail haemocyanin which is split by a change in *p*H but not by salt (example: *Paludina vivipara*), and a third type which is split only at extremely low and extremely high *p*H values and not by salt (example: *Buccinum undatum*).

The origin of the lowest class of the vertebrates possessing red corpuscles, the *Cyclostomata* (lamprey and hagfish) has long been a question of controversy among taxonomists. The opinion now generally accepted looks upon these worm-like fishes as belonging to a very ancient side branch on the genealogical tree of the vertebrates, far removed from other living animals. The determination of the molecular weight of the red blood-pigment for the various groups of vertebrates by means of the ultracentrifuge gave the result that all vertebrates, including the different types of fish, with the exception of the *Cyclostomata*, show a value of about 69,000; the *Cyclostomata*, however, give a value of only one-fourth of this, or 17,500. Sedimentation analysis, therefore, strongly supports the result arrived at from morphological, anatomical, and palaeontological indications. To put it crudely, man is more closely related to the salmon than the salmon is to the lamprey.

Many other instances of the use of molecular sedimentation analysis in taxonomy could be given, but only one more, from the field of botany,

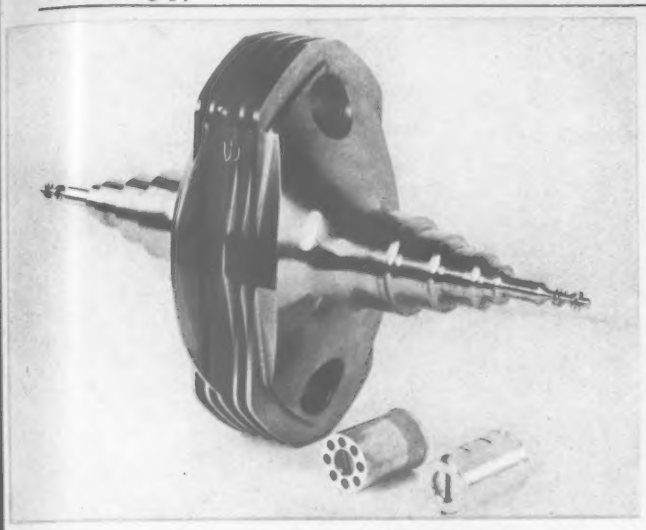


FIGURE 1 – *Rotor and cell for the oil-turbine ultracentrifuge. Beside the solution cell to the right is shown a cell for static and dynamic balancing.*

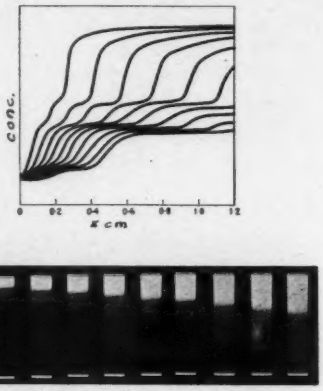


FIGURE 2 – *Sedimentation diagram of the protein molecules in the blood of the horse-shoe crab,* Limulus polyphemus, *taken by means of the light-absorption method.*

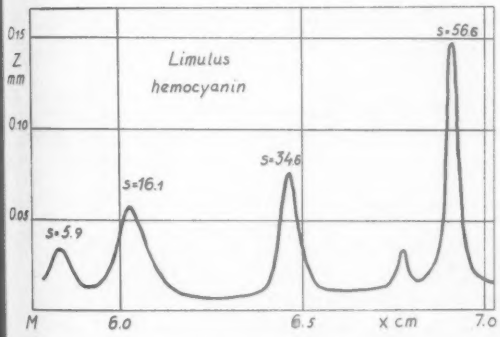


FIGURE 3 – *Sedimentation diagram of the same object taken by means of one of the refractive index methods.*

FIGURE 4 – *Sedimentation diagram of cellulose nitrate dissolved in acetone. (The cellulose used was a precipitated fraction of wood cellulose.)*

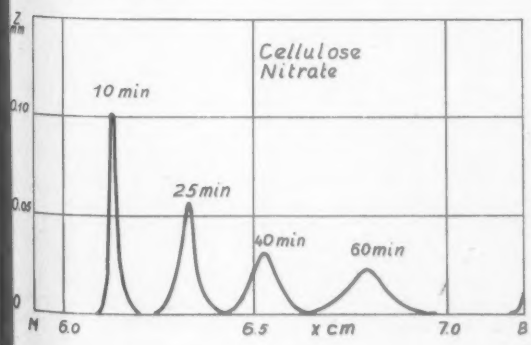
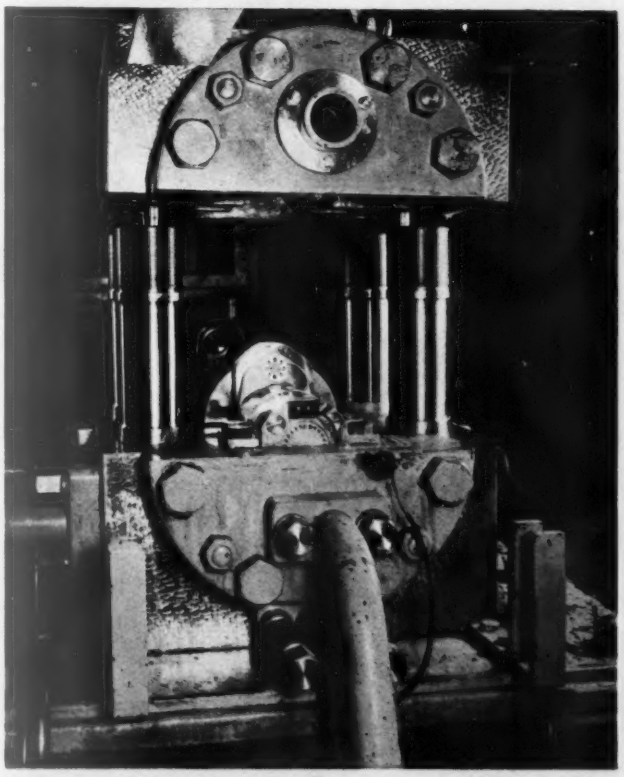


FIGURE 5 – *View of ultracentrifuge, showing the rotor in position and the heavy steel lid raised above the bolts which serve to hold the parts together.*



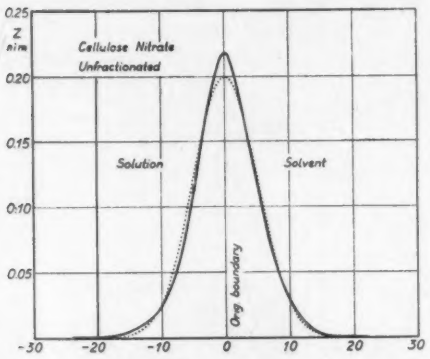


FIGURE 6 – *Diffusion diagram of cellulose nitrate dissolved in acetone. (An unfractionated sample of cellulose was used.)*

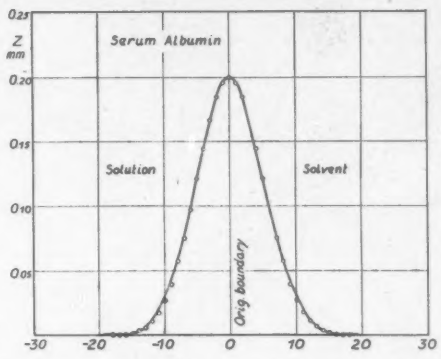


FIGURE 7 – *Diffusion diagram of serum albumin.*

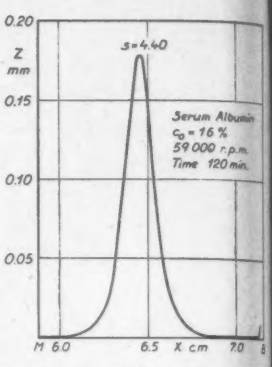


FIGURE 8 – *Sedimentation diagram of serum albumin.*

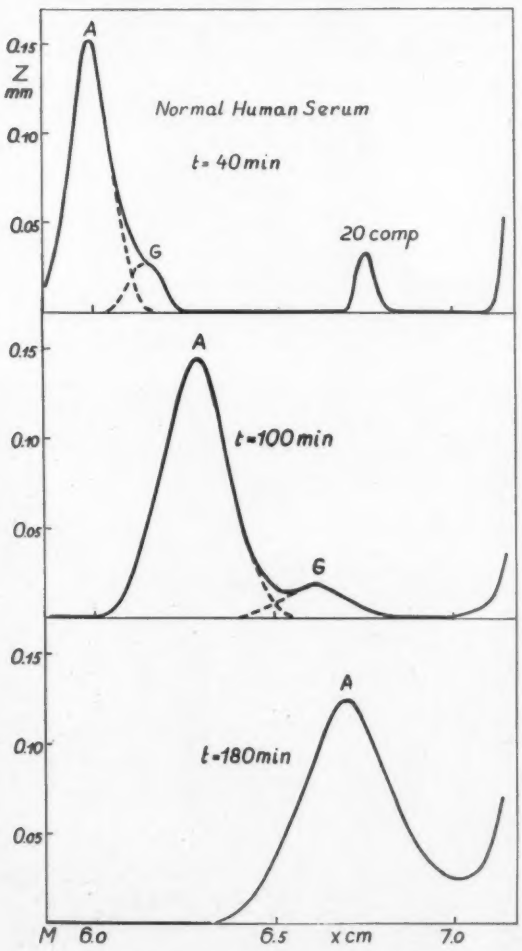


FIGURE 9 – *Sedimentation diagram of normal human serum, showing three peaks* (A, G, *and* 20-*comp.*). *See page* 93.

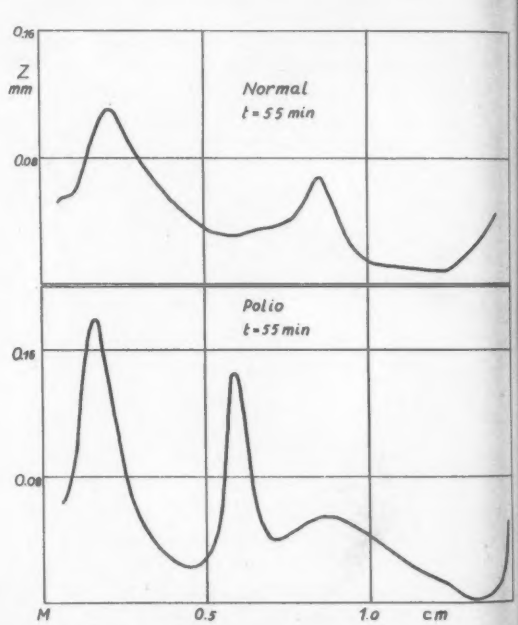


FIGURE 10 – *Sedimentation diagrams of brain extract containing poliomyelitis virus and other high-molecular proteins and of virus-free brain extract.*

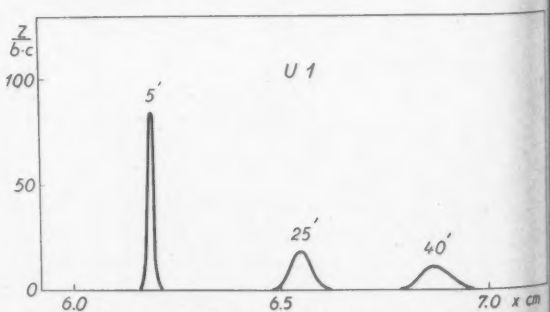


FIGURE 11 – *Sedimentation diagram of unbleached cotton linters which have been nitrated and dissolved in acetone. The molecular weight (m.w.) is 1·9 millions, corresponding to a degree of polymerization (d.p.) of* 6,000.

will be cited here. The sap in the bulbs of the *Liliiflorae* contains polysaccharides and sometimes also proteins in solution. An ultracentrifugal investigation gave the following result. Among the species of the same genus there is a pronounced similarity with regard to the material of high molecular weight. The *Lilium* species, for instance, contain a large amount of polysaccharide, while species of *Fritillaria* and *Tulipa*, belonging to the same subfamily as *Lilium*, contain more protein than carbohydrate and show sedimentation diagrams quite different from those of *Lilium*. There is one very interesting exception: *Fritillaria kamchatkensis*, which is closely related to the *Lilium* (and which has been placed by some taxonomists within this genus), yields a diagram of the *Lilium* type.

The medical applications of ultracentrifugal sedimentation are numerous. One of the most interesting examples is the disentanglement of the complicated protein system of the blood-plasma. Normal serum shows three boundaries (see figure 9). The first one, the so-called 20-component fraction, sediments to the bottom of the cell in about forty minutes under standard conditions (room temperature and 250,000 times gravity). In concentration it corresponds to only a few per cent. of the total protein in the serum. Its molecular weight is of the order of half a million. At the same time as the first boundary reaches the bottom of the cell, a second broad boundary has usually just separated from the top of the solution. As it moves towards the periphery it eventually splits into two boundaries. The first, and smaller, one reaches the bottom in 1½–2 hours; it has a molecular weight of 150,000–180,000, and in concentration it amounts to 10–20 per cent. of the total. Finally, the major part of the protein sediments in the last boundary, which reaches the bottom of the cell in about three hours. This boundary, however, does not correspond to a single substance, but represents a protein called β-globulin as well as the serum albumin. The composite nature of the third boundary is easily demonstrated in the case of normal human serum. If, before the run, the serum is diluted with an equal volume of 0·2 molar disodium phosphate instead of with physiological saline, the third boundary will separate into two boundaries towards the end of the run. The first and bigger boundary shows the same sedimentation as before. It consists of the serum albumin, which has a molecular weight around 70,000. The more slowly moving boundary consists mainly of β-globulin, which is a lipo-protein. The density of this protein is close to 1, whereas the density of most other proteins is about 1·3. The sedimentation of the lipo-protein is therefore much more dependent on the density of the solution than that of the other proteins. This property of the lipo-protein has been used for its separation from normal human serum.

Up to the present no other mammalian sera have been found to contain such a low-density lipo-protein as the one in human serum. There are, however, many reasons for believing that other mammalian sera also have a β-globulin which sediments with the albumin, but its lipid part has a higher density than the human one.

The general appearance of the sedimentation diagram from normal adult mammalian serum seems to be qualitatively the same for all species, but there are usually some small quantitative differences. Even the lower vertebrates seem to give qualitatively the same sedimentation diagrams as the mammals do. The *Cyclostomata*, however, have a minor component with a molecular weight of about 35,000 and a major component with a molecular weight of about 360,000.

The sedimentation diagram for a given animal is not always the same, but varies with its age. Thus the ultracentrifuge has revealed that a hitherto unknown serum protein, now called fetuin, is present in many foetal sera and in sera from newly born animals. It has a lower molecular weight (around 50,000) than any of the previously isolated serum proteins.

Antibody production during the process of immunization is often manifested in the serum diagram as an increase in either the so-called γ-globulin or in the heaviest protein component. Some diseases also produce great changes in the serum sedimentation diagrams, and it may be possible, for instance, to classify various myelomas according to the sedimentation diagrams obtained from the patient's serum.

The changes in a serum due to the increasing age of the animal may be illustrated by bovine serum. In the foetal serum diagram hardly any γ-globulin is perceptible. Besides an asymmetric peak consisting of albumin and fetuin, a small amount of a heavy component is present. A similar diagram is obtained from the serum just after birth. Some time after the calf has received colostrum, γ-globulin appears in the serum diagram. During the first weeks after birth the fetuin and the γ-globulin decrease. Later the fetuin practically disappears, whereas the γ-globulin

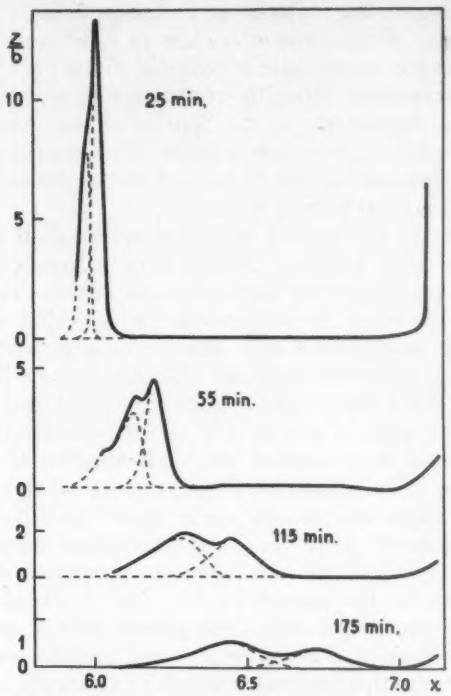


FIGURE 12 – *Sedimentation diagram of native wood cellulose obtained by extraction with cuprammonium. Two maxima are to be seen, one representing the cellulose proper (m.w. = 700,000, d.p. = 4,300) and the other wood polyoses (hemicellulose).*

increases, when the natural immunity is being built up, until it reaches its 'natural' level.

Another medical application is in the study of viruses. Directly after the first preparation of virus crystals (tobacco mosaic) the analytical ultracentrifuge was used for the determination of the mass of these huge molecules and to compare various strains of virus. A great number of such determinations have been made during the last ten years.

Sedimentation measurements in the ultracentrifuge have proved very useful as a means of following the process of purification of a virus. As an example, the isolation of poliomyelitis virus from brain tissue or intestinal contents may be mentioned. In figure 10 are given the sedimentation diagram of brain extract containing both virus and other high-molecular proteins (three peaks), as well as a control diagram of the virus-free brain extract.

Many industrial problems concerning material of high molecular weight belonging to the polysaccharides and to various groups of synthetic organic polymers have been studied by means of ultracentrifugal sedimentation. The most important of the macromolecular carbohydrates, from a technical point of view, is cellulose. It occurs in a fairly pure state in certain fibres such as cotton and flax. Native cellulose, however, generally occurs in combination with other carbohydrates and with lignin, and its liberation requires rather drastic chemical treatment (the sulphite and sulphate processes).

For many purposes the industrially prepared cellulose should contain molecules consisting of the longest possible chains of glucose groups, and it is often considered advantageous that the length of the individual molecules should be nearly equal (monodisperse). In the industrial processes for isolating cellulose from wood a considerable degradation takes place, especially during the later stages. The chain molecules break, and shorter and more unequal (polydisperse) pieces result. It is of considerable importance to find the most favourable conditions for producing a cellulose of a specified molecular type. Investigations of this kind have been carried out by means of the ultracentrifuge. An example of a comparatively monodisperse cellulose of very long chain molecules is given in figure 11. Native wood cellulose, on the other hand, is much more polydisperse (figure 12).

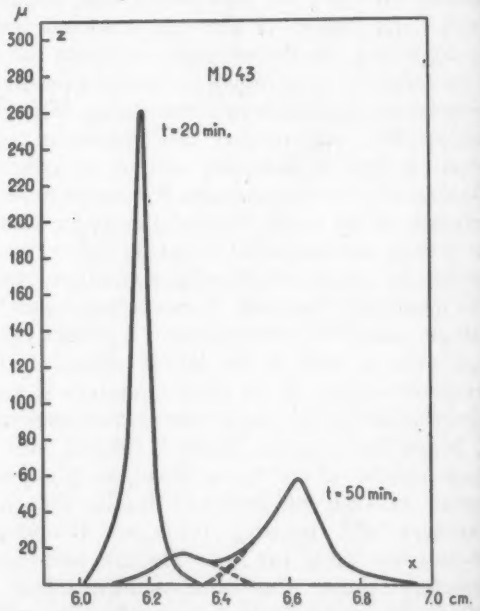


FIGURE 13 – *Sedimentation diagram of sulphite cellulose nitrated and dissolved in acetone (m.w. = 530,000, d.p. = 1,850).*

Industrial wood cellulose manufactured according to the sulphite process is broken down considerably, and the amount of wood polyoses is diminished (figure 13).

In such cases as cellulose, where the broadening of the sedimentation curves is caused entirely by the different rate of sedimentation of the individual molecules, a measure of the polydispersity is obtained by calculating dB/dx, the rate of broadening with increasing distance from the centre of rotation (cf. figure 4).

The complete description of a polydisperse material such as cellulose requires the determination of the distribution or frequency curve for the weights of the molecules. This problem is very difficult, and so far only approximate solutions have been found. In figure 14 are given the frequency curves for two commercial cellulose materials, computed from sedimentation data.

Among the synthetic high polymers and their natural prototypes rubber plays an important role. The technical value of various types of rubber depends to a considerable extent upon the size and shape of the molecules. Here sedimentation analysis in the ultracentrifuge has furnished valuable information. In the case of neoprene it was found that bulk polymerization gives molecules of simple chain type, while certain kinds of emulsion polymerization produce molecules of a more branched type. For most purposes it is desirable to obtain a rubber with simple chains, and therefore the polymerization process should be conducted in such a way as to yield that type of molecule. Also in the case of plastics, such as polystyrene, methyl methacrylate, and other polyethylenes, the ultracentrifuge has been used for the control of industrial processes.

Above I have tried to indicate how by means of studying molecular sedimentation we have been able to collect a wealth of facts concerning material of high molecular weight, both native substances built up within the living organism such as proteins and carbohydrates, and artificially produced macromolecular substances such as plastics. The ultracentrifugal method is, however, by no means the only one for the study of these problems. There are also electron microscopy, X-ray analytical methods, osmotic methods, diffusion measurements, viscosity methods, and so on.

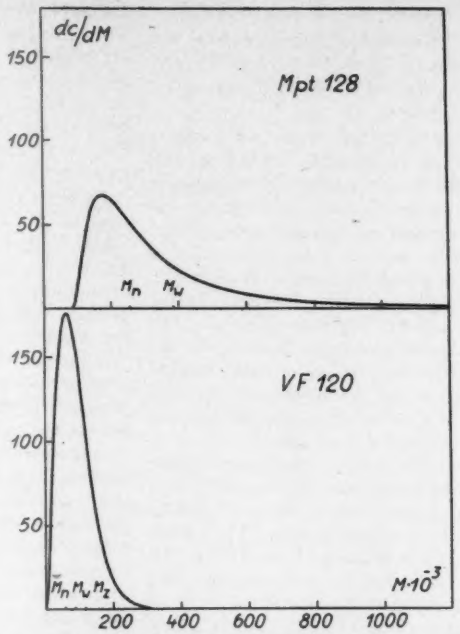


FIGURE 14 – *Frequency curves for two different cellulose materials nitrated and dissolved in acetone.*

Book reviews

ODYSSEY OF A BOTANIST

A Botanist in Southern Africa, *by John Hutchinson. Pp. xii + 686, with numerous photographs, drawings, and maps. P. R. Gawthorn Limited, London.* 1946. 45*s. net.*

This is a fine book, and one cannot do justice to it in a short review. The illustrations alone are a remarkable contribution to botanical literature, including numerous line drawings of living South African plants in Dr Hutchinson's well-known and most attractive style; a superb series of photographs which show many of the plants growing in their natural habitats; and various maps showing geographical distribution. The text takes the form of an account of the various journeys made by Dr Hutchinson and his companions, and of the plants which they encountered. There are sections on the floral regions of South Africa, the history of botanical exploration in the country, and allied matters, so that the book has the double value of a travel story and a student's handbook. There is a foreword by General Smuts, who figures largely in the book and who in fact made much of the work possible. The whole production is a monument to Dr Hutchinson's energy, botanical insight, and artistic skill; to the enterprise of Messrs Gawthorn, who published, at a very difficult time, an expensive book of a type which is too rarely seen in this country; and to the public spirit of General Smuts and other South African botanists.

T. A. STEPHENSON

A HISTORY OF CHEMISTRY

Die Entwicklungsgeschichte der Chemie, *by H. E. Fierz-David. Pp.* 425. *Verlag Birkhäuser, Basel.* 1945. 21.50 *Swiss francs.*

This attractive book, with over a hundred illustrations, including portraits and reproductions from old books, is not a formal history of chemistry but is intended to interest and instruct chemists who have no opportunity of studying original sources. It deals with the origins of chemistry, alchemy, the period from Boyle to Lavoisier, the atomic and molecular theories, and the development of pure and applied chemistry in the nineteenth century. The author explains that he has not used original sources but has drawn his material from books, and in some cases he does not seem to have made use of more recent publications which would have been helpful to him. The collection of miscellaneous book titles in the appendix serves no useful purpose, and could have been replaced by a list of books on the history of chemistry which would have supplied the many gaps in the story now presented. Although the text is generally accurate and informative, there are lapses, as when Faraday is put before Berzelius in the development of the electrochemical theory, and in the account of the theory of valency Frankland is not mentioned. The author has managed to cover a large field in an interesting manner, and all chemists who read German will find the book attractive. To the historian of chemistry it will be less useful, but the author does not claim to have had his requirements in mind. The references, however, will disclose some interesting features even to the expert, and the book is one which should find its place in the field of historical works.

J. R. PARTINGTON

PHYSICS AND PHILOSOPHY

Fundamental Theory, *by Sir A. S. Eddington. Pp. viii* + 292. *University Press, Cambridge.* 1946. 25*s. net.*

There will be few (and an experimental physicist cannot be expected to be among them) who will be able to understand in full detail all the profound and subtle arguments developed in this remarkable posthumous treatise on the fundamental particles and constants of nature, which is edited by Sir Edmund Whittaker. Eddington investigates the way in which structures are related to the uncertainty constant of the frame of reference, and already by page 10 obtains a simple relation between the range constant of nuclear force and the speed of recession of nebulae, thus straddling physical concepts from the atomic nucleus to the cosmos.

The book is rich in brilliant analogy and is enlivened by unexpected flashes of humour, despite its profundity. Important concepts developed include the replacement of gravitation by a 'mechanical' exclusion principle corresponding to the 'electrical' exclusion principle of Pauli. Eddington's now well-known epistemological theory for the number of particles in the universe is linked up with the general derivation of atomic constants. By adopting experimental values for three natural constants other atomic constants can be obtained, the agreement with observation being startling. To select two examples only, (*a*) fine structure constant; observed = 137·009, theoretical = 137; (*b*) ratio of masses proton/electron; observed = 1,836·27, theoretical = 1,836·34. The theory, among other matters, also predicts the existence of mesotrons of respectively 174 electron masses and 2·38 proton masses.

Only time can decide the ultimate importance of this outstanding contribution to physics and philosophy.

S. TOLANSKY

FREE RADICALS

The Chemistry of Free Radicals, *by W. A. Waters. Pp. viii* + 295. *The Clarendon Press, Oxford.* 1946. 20*s. net.*

Free radicals were at one time little more than chemical curiosities, yet the essential part which they play in many of the familiar reactions of organic chemistry can be judged by the very wide scope of this book, which appears at a most opportune moment. It is still possible in a single volume to give a comprehensive account of this rapidly expanding subject. Some of the earlier ground is well known, e.g. the discovery and properties of the radicals of the triphenylmethyl and diphenyl nitrogen types.

Chapters in the book are devoted to the parts played by free atoms of hydrogen, oxygen, chlorine, and sodium in gaseous reactions and photochemical decompositions. The author deals also with reactions which are catalysed by free radicals, including halogen atoms, peroxide catalysed reactions, and the chain polymerization of olefines. Of particular interest are the chapters dealing with free alkyl radicals and their reactions in solution, and with the production and properties of the free aryl radicals generated in solution by the decomposition of diazo compounds, to our knowledge of which the author has himself made outstanding contributions. The final chapters deal with reactions involving metals as free radicals, oxidation processes, and some possible applications of free radical chemistry to biochemical processes.

W. BAKER

RELAXATION METHODS

Relaxation Methods in Theoretical Physics, *by R. V. Southwell. Pp. vi* + 248. *Oxford University Press, London.* 1946. 20*s.* net.

Interest in relaxation methods for use in design and research is steadily growing as their power and range become more widely known. Many will be glad that, in addition to developing the methods, the author has taken the trouble to write a connected account of them for those who wish to understand, and even more for those who wish to use, them. Space forbids a description of the methods, but numerical solutions to a wide variety of problem, some of which still defy 'orthodox' analysis, are obtained, and are exhibited very clearly and with considerable detail in a series of diagrams. In each of the thirty-five specific problems solved the 'background' is skilfully summarized before computational details are given, so that the reader has a complete 'case-history' to enable him to treat with confidence and understanding similar problems which he may encounter. The author is to be congratulated upon an exposition orderly, lucid, and detailed, and the publishers upon the production of a very handsome volume at a very reasonable price. Nor must some credit be withheld from the research team, without whom, as the author generously admits, such a striking set of results could hardly have been obtained.

W. G. BICKLE

Notes on contributors

R. E. PEIERLS,
C.B.E., M.A. (Cantab.), D.Sc. (Manchester), D.Phil. (Leipzig), F.R.S.,

Was born in Berlin in 1907. Following continental practice he studied at many universities—Berlin, Munich, Leipzig, and the Federal School of Technology, Zürich. He was attracted to theoretical physics and carried out research under Heisenberg at Leipzig and under Pauli at Zürich, his two main fields of interest being the quantum theory of metals and other solid materials and the fundamental problems of field theory. In 1932 a Rockefeller Fellowship took him to work for a winter under Fermi at Rome and later to work with Dirac at Cambridge.

Political events in Germany made Peierls decide to remain in England. In 1935 he went to Cambridge to work in the Mond Laboratory. In 1937 he was appointed Professor of Applied Mathematics at Birmingham. Shortly after the outbreak of war Peierls worked closely with O. R. Frisch, and the two became convinced of the importance of pressing ahead with the development of atomic energy. Within a short time he was giving his whole time to the British atomic energy project. Later he worked in America. He returned to Birmingham in 1946 and is now consultant to the Atomic Energy Department of the Ministry of Supply. He has been associated with the Atomic Scientists' Association since its formation.

SIR EDWARD J. SALISBURY,
C.B.E., D.Sc., F.R.S., F.L.S.,

Has been Director of the Royal Botanic Gardens, Kew, since 1943 and is Biological Secretary of the Royal Society. He was born in 1886 and was educated at University College School and University College, London. His numerous academic appointments have included that of Lecturer at University College, London (1918), Reader in Plant Ecology (1924), and Quain Professor of Botany (1929–43). He was elected a Fellow of University College in 1920. Among the many offices he has held in scientific societies and institutions may be mentioned those of Vice-President of the Royal Society (1943), President of the British Ecological Society (1928), and Fellow of Queen Mary College (1938). He was a member of the Agricultural Research Council from 1940 to 1944. From 1934 to 1944 he was a Member of the Senate of the University of London. He is a member of the Scientific Advisory Council to the Cabinet, of the Agricultural Improvement Council, and of the University Grants Committee.

C. S. GIBSON,
O.B.E., M.A., Sc.D., F.R.S., F.R.I.C.,

Has been Professor of Chemistry in London University and Guy's Hospital Medical School since 1921. He was born in 1884 and was educated at Manchester Grammar School and Corpus Christi College, Cambridge. He has held appointments as Senior Research Student of the Goldsmiths' Company at Oxford University (1909–12), Assistant Lecturer and Demonstrator in the University Chemical Laboratory, Cambridge, Professor of Chemistry in the Maharaja's College, Trivandrum (1912–19), and Professor of Chemistry, Egyptian Government School of Medicine (1919–20). From 1924 to 1933 he was Honorary Secretary of the Chemical Society, of which he writes in this issue.

DAVID S. EVANS,
Ph.D., F.Inst.P.,

Was born in 1916 and was educated at Cardiff High School for Boys and King's College, Cambridge. After graduation he undertook research at Cambridge on the Stark effect in the hydrogen lines of the spectra of double stars. In 1938 he joined the staff of the University Observatory, Oxford. During the war he was engaged in research on physical problems relating to medicine. He has always had a keen interest in popular scientific writing and was formerly on the editorial board of *The Observatory* and advisory editor of *Discovery*. His book *Frontiers of Astronomy* was reviewed in our January 1947 issue. He has recently taken up an appointment as Second Assistant at the Radcliffe Observatory, Pretoria.

C. H. WADDINGTON,
M.A., Sc.D., F.R.S.,

Was born in 1905 and was educated at Clifton College and Sidney Sussex College, Cambridge. After graduation he undertook biological research, studying the evolution of fossils, the genetics of plants, and the development of animals. He has travelled extensively and collaborated with scientists in many foreign countries. Besides contributing about fifty papers to scientific journals he is the author of several books: *How Animals Develop*, *Introduction to Modern Genetics*, and *Organisms and Genes*. During the war he was Scientific Adviser to the Commander-in-Chief of Coastal Command, Royal Air Force. He has just taken up appointments as Professor of Animal Genetics in the University of Edinburgh and as Chief Geneticist to the National Animal Breeding Research Organization of the Agricultural Research Council.

R. F. BARROW,
B.Sc., D.Phil., A.R.C.S.,

Was born in London in 1916 and was educated at Cranleigh School, Surrey, and the Royal College of Science, London. In 1937 he came in contact with W. Jevons at the Royal College of Science, and for two years worked with him on problems of chemical spectroscopy. In 1939 he came to Oxford as a Ramsay Memorial Fellow, with the intention of continuing this kind of work. On the outbreak of war, however, he joined Professor Hinshelwood's team of research workers engaged on work for the Ministry of Supply. In 1944 he was elected Lecturer in Chemistry at Jesus College, Oxford.

THE SVEDBERG,
Ph.D., D.Sc., D.Med., D.Techn., For. Mem. R.S.

Was born in 1884 and was educated at the schools in Köping, Örebro, and Gothenburg and the University of Upsala. After obtaining his doctor's degree in 1907 he remained at the university as *Docent* and was appointed professor of physical chemistry in 1912. He is a member of many Swedish and foreign learned societies. In 1923 he acted as visiting professor of colloid chemistry at the University of Wisconsin, U.S.A. In 1926 he received the Nobel prize for chemistry. His scientific work has chiefly been concerned with the physics and chemistry of colloids and high-molecular substances such as proteins, polysaccharides, and synthetic polymers. His books include *Colloid Chemistry* (New York, 1923 and 1928) and *The Ultracentrifuge* (with Kai O. Pedersen) (Oxford, 1940).

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